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Assessing The Potential For Reducing Disease Control Inputs On Carrot Using Disease Resistant Cultivars

Project Year End Report For 1995

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Assessing The Potential For Reducing Disease Control Inputs On Carrot Using Disease Resistant Cultivars

Identification of Need

Carrots represent an important vegetable crop to the State of Wisconsin. The Wisconsin carrot crop is grown on approximately 4,400 acres for an average crop value of approximately $2,100 per acre. The crop is grown primarily on muck soil, although in the past five years, acreage on irrigated loamy sand in central and southern Wisconsin has increased. Most of the acreage is grown for processing, slicing and dicing carrots, although one producer in southeast Wisconsin grows a sizable acreage for fresh market consumption. Because most Wisconsin carrots are used for processing, the value per unit ($4.77 per cwt) is lower than other states such as California where the carrots are used more for fresh market. Wisconsin ranks fourth in the total U.S. carrot production and in 1994, the carrot crop contributed $8,394,000 to the state's farm economy. The 1995 growing season in Wisconsin was not representative of the production of the Wisconsin carrot industry. Excessive heat and untimely flooding greatly reduced yields and quality.

Weather conditions in Wisconsin typically favor infection of the carrot foliage by two fungal pathogens *Alternaria dauci* (Alternaria leaf blight) and *Cercospora carotae* (Cercospora leaf blight). Both diseases are commonly observed in most fields at some time during the growing season. The occurrence of dew and other sources of leaf wetness helps to determine the appearance of both of these fungal incited diseases and subsequent spread through the field. Both diseases attack the foliage and gradually debilitate the affected plants. Yields of affected plantings are reduced (estimated up to 25%) and premature defoliation affects plant vigor and root quality. Cercospora leaf blight is especially serious on fresh market carrots since it attacks and weakens the petioles. Healthy petioles are important in the harvest of fresh market carrots since the harvester grasps onto the foliage and pulls the carrots from the ground. Breakage of petioles at harvest due to extensive Cercospora infection interferes with harvest and badly infected carrots are left in the field because they cannot be harvested with existing machinery.

Wisconsin growers traditionally treat carrot acreage with multiple applications of fungicide beginning when the first plantings have reached the 6 to 9" stage in mid-June and the first symptoms of disease are beginning to appear. Fungicide sprays continue at 7-14 day intervals depending on IPM scouting reports and weather conditions. Fields may be treated with fungicide 5-10 times during a "normal" growing season. Within a field planted to multiple carrot cultivars, no distinction is made in cultivar susceptibility to Alternaria and Cercospora leaf blights. The entire planting is generally sprayed according to the most susceptible cultivar. The fewest sprays are applied to the early planted and early harvested fields and the greatest number of sprays applied to the fields harvested late in the growing season. The cost of treatment with a standard fungicide program can be substantial depending on the frequency of application (Table 1).

Table 1. Cost of fungicide treatment for control of Alternaria and Cercospora leaf blights of carrot.

		Number of Fungicide Applications			
Brand Name	Rate	1	4	8	10
Bravo Ultrex	1.4 lb/A	$9.80	$39.20	$78.40	$98.00

Carrot cultivars available for planting in Wisconsin have traditionally been susceptible to both Alternaria and Cercospora leaf blights. Recently breeding efforts on the part of several seed companies have begun to develop carrot cultivars for fresh market and processing markets with a high level of resistance to both diseases. The planting of cultivars with blight resistance that require fewer fungicide sprays for disease control could dramatically reduce the amount of fungicide inputs and the disease control inputs applied by the grower. This in turn would lead to a lower unit cost of production and will help to improve the competitive position of Wisconsin's carrot industry.

Statement of Objectives

1. To assess the value of host resistance in controlling carrot leaf blights in larger scale plots in a grower's field using standard grower practices for all procedures except fungicide application.

2. To determine if host resistance and fungicide application are additive in controlling carrot leaf blights, permitting adequate disease management to be obtained with decreased fungicide application on carrot lines with host resistance.

3. To determine if a normal yielding crop can be produced with decreased fungicide application when carrot lines incorporating host resistance are used.

Methods Used in the 1995 Field Trial

This trial was established to obtain a second year of data assessing the relative value of host resistance and fungicide treatment in controlling carrot foliar leaf blights. The research was conduced in large scale plots in a grower's field using standard grower practices for all procedures except fungicide application. The experiment was designed to determine if use of carrot lines incorporating host resistance would permit adequate disease management and normal yields to be obtained with decreased fungicide application. Seeds of four carrot cultivars known to have varying levels of resistance to foliar blights were machine-planted in large plots at the R. S. Kincaid Farm, Palmyra, WI. The experiment was planned as a 4 x 4 factorial in a split-plot design with four replications. The four carrot cultivars made up the main plots and fungicide treatments were randomly assigned to the sub-plots. Each plot spanned two 3-foot wide raised beds with two 45-foot-long rows planted in each bed. To minimize interplot interference and provide uniform inoculum throughout the trial, pairs of beds planted with the susceptible cultivar Lucky B separated plots in one dimension and 10-foot wide open alleys were located between the ends of adjacent plots. Soil type was a Houghton muck, pH 7.7. Plots were fertilized with 600 lb/A of 0-0-60 and 150 lb/A of 18-46-0 broadcast preplant. Insects were controlled with foliar applications of Diazinon AG500 (16 oz/A, June 29) and Ammo 2.5 EC (5 oz/A, July 13, July 21, July 28, August 3 and August 10). Weeds were controlled with application of Linex 4L (1 pt/A, June 14; 2 pt/A, June 29), Poast (1.5 pt/A, July 13) and Linex 50W (2 lb/A, July 28). Fungicide treatments were applied from July 12 through September 1 using the grower's equipment delivering 51 gal/A at 40 psi. A 10-foot wide boom equipped with Tee-Jet 8003VS nozzles spanned two beds at a time. Bravo Ultrex, 1.4 lb/A, was applied to each of the four types of carrots included in the trial according to four treatment schedules. These consisted of: 1) untreated control, 2) eight fungicide applications (weekly beginning July 12), 3) five fungicide applications (7/19, 8/3, 8/21, 8/26, 9/1) and 4) three fungicide applications (7/27, 8/21, 9/1). Disease severity was rated at 10-14 day intervals from July 19 to September 8 using the Horsfall-Barratt system. Total rainfall and irrigation (May-September) was 24.85 inches.

Results of the 1995 Field Trial

Alternaria and Cercospora leaf blights are favored by prolonged periods of leaf wetness from rain and dew. Above average rainfall during late July and August favored disease spread. By the third week of August, over 60% of the unsprayed Lucky B plots exhibited symptoms of these diseases (Table 1, Fig. 1). Cooler and dryer conditions during late August and early September were more conducive to growth of new carrot foliage and the proportion of symptomatic vs. healthy foliage declined. Lucky B and Heritage were the most susceptible cultivars in the trial while Eclipse was intermediate in susceptibility and Convert was the most tolerant cultivar. Treating Lucky B eight times with fungicide significantly reduced disease severity when compared to the unsprayed Lucky B plots, but the level of disease in these treated plots was still significantly higher, as measured by the relative area under the disease progress curve (AUDPC), than untreated plots of Convert (Table 1, Fig. 2). Fungicide treatment was more effective in reducing disease severity on Heritage than on any of the other cultivars (Table 2) . Treating Convert with any number of sprays did not significantly reduce disease when compared with the unsprayed plots of Convert. Only marginal benefits of fungicide treatment, five and eight times, were observed on Eclipse. These data demonstrate significant differences in disease susceptibility in the carrot cultivars tested in this field trial. Yields were significantly lower in all plots than yields observed in 1994 (Table 3-6, Fig. 3). Infection of the foliage by the Alternaria and Cercospora leaf blight pathogens significantly reduced yield of Heritage, Eclipse and Lucky B cultivars, but not Convert. Treatment of Heritage, Eclipse and Lucky B with even three sprays of fungicide increased yield above the untreated check plots. Additional sprays of fungicide, even on the most susceptible cultivar Lucky B, did not significantly improve yield. Fungicide treatment had the greatest impact on crop values when the treatments were applied to Heritage and Lucky B (Fig. 4). Treatment of Eclipse and Convert with three sprays of fungicide provided marginal increases in crop value. Treatment of Eclipse with 5 and 8 sprays of fungicide and Convert with 8 fungicide sprays reduced crop values below the crop value of the untreated check plots of these cultivars (due to the cost of chemical applied). Using these yields and crop values as a guide, there is marginal to no benefit in treating the most resistant cultivar, Convert, with any amount of fungicide while significant benefits accrued when the most susceptible cultivars Heritage and Lucky B were treated with as many as 8 fungicide sprays.

Discussion

Field studies during 1993-95 assessed disease development on unsprayed carrot cultivars and breeding lines in an effort to determine the magnitude of disease resistance available to growers and present in commercial and university breeding programs. During 1995, this field plot contained 75 plot entries. These studies conclusively demonstrated higher levels of disease resistance in many of the plot entries than is present in the cultivars currently grown in Wisconsin for processing and fresh market. During 1994, a trial using the cultivars Lucky B and Eclipse and breeding lines XPH 3740 and XPH 3906 and a similar plot design as the current study outlined above demonstrated the potential for reduced fungicide inputs when disease resistant cultivars are grown using practices typical of commercial production. The 1995 field trial using the cultivars Lucky B, Heritage, Eclipse and Convert treated with 0, 3, 5 or 8 fungicide sprays once again demonstrated that carrots can be successfully grown in Wisconsin with substantially fewer fungicide sprays. It should be noted that total yield for Convert with no fungicide application was significantly higher than Heritage with no fungicide applied indicating potential for obtaining good yield from this cultivar with lower fungicide input. However, Convert was graded as a dicer type (minimum diameter for marketable yield = 1.25

in.) and the other three cultivars were graded as slicer types (minimum diameter for marketable yield = 0.75 in.). Since Convert was graded on a different scale it made the marketable yield appear to be lower than it would have been if all cultivars had been graded into the same size categories. The greatest value of fungicide treatment of Heritage was observed when this cultivar was treated with 3 sprays of fungicide, while the greatest value of treating Lucky B was observed when 5 fungicide sprays were applied. Marginal benefits were observed when Eclipse and Convert were treated with fungicide sprays. Adjusting fungicide rates and treatment schedules to account for resistance of each cultivar may provide both economic and environmental benefits through improved disease control, increased yield, and reductions in use of unneeded fungicides. The cost per spray of a standard fungicide program using Bravo Ultrex at 1.4 lb/acre is $9.80 per acre (based on the retail cost for Bravo Ultrex of $7.00/lb). If all acres of carrot production in Wisconsin (4,400 acres in 1994) were planted to a cultivar with increased resistance to Alternaria and Cercospora leaf blights and a single fungicide spray was saved on each acre because of this improved disease resistance, growers would have saved $43,120 plus application costs and they would have applied over 3 tons less fungicide to their fields.

Wisconsin carrot growers are currently limited to chlorothalonil and fixed copper fungicides for management of foliar diseases. Because of the efficacy of chlorothalonil sprays, most growers treat with this material several times during the growing season. With limited options for disease control and the cost of production inputs an important element in the economic viability of growers, improvement of disease resistance of cultivars with high yield and quality potential is a critical need for the Wisconsin carrot industry.

Table 1. *Effect of treatment on foliar blight development and area under the disease progress curve.*

Cultivar	Treatment schedule	Mean foliar blight 7/19	8/3	8/10	8/23	8/28	9/8	Relative AUDPC [1]
Heritage	Untreated Control	0.7	2.4	8.1	55.3	76.0	72.8	0.31
	Bravo Ultrex, 1.4 lb/A, three week intervals (3 sprays) [2]	0.4	1.8	5.1	38.1	53.7	61.3	0.23
	Bravo Ultrex, 1.4 lb/A, two week intervals (5 sprays) [3]	0.5	1.8	5.2	29.0	50.4	57.2	0.20
	Bravo Ultrex, 1.4 lb/A, weekly (8 sprays) [4]	0.7	1.0	3.7	21.2	16.1	24.0	0.10
Eclipse	Untreated Control	0.7	1.8	8.4	29.2	27.4	37.8	0.15
	Bravo Ultrex, 1.4 lb/A, three week intervals (3 sprays) [2]	0.8	1.7	6.0	28.4	26.8	38.9	0.15
	Bravo Ultrex, 1.4 lb/A, two week intervals (5 sprays) [3]	0.5	1.0	6.1	20.2	21.7	30.6	0.11
	Bravo Ultrex, 1.4 lb/A, weekly (8 sprays) [4]	0.7	1.3	4.3	15.2	17.5	26.9	0.09
Lucky B	Untreated Control	0.9	3.9	15.8	64.3	79.8	60.2	0.35
	Bravo Ultrex, 1.4 lb/A, three week intervals (3 sprays) [2]	0.4	3.7	10.4	55.5	72.2	59.4	0.30
	Bravo Ultrex, 1.4 lb/A, two week intervals (5 sprays) [3]	0.5	3.1	9.7	36.4	54.1	48.8	0.22
	Bravo Ultrex, 1.4 lb/A, weekly (8 sprays) [4]	1.0	3.2	5.4	26.9	38.5	44.7	0.17
Convert	Untreated Control	1.1	2.7	11.7	17.3	11.6	11.0	0.09
	Bravo Ultrex, 1.4 lb/A, three week intervals (3 sprays) [2]	0.7	2.9	7.5	15.7	10.0	9.1	0.08
	Bravo Ultrex, 1.4 lb/A, two week intervals (5 sprays) [3]	0.7	3.2	8.0	15.1	10.0	11.1	0.08
	Bravo Ultrex, 1.4 lb/A, weekly (8 sprays) [4]	1.2	2.3	4.6	11.3	10.2	12.0	0.06
LSD ($P = 0.05$) [5]		NS	1.1	3.2	9.7	10.7	13.3	0.04

1 Relative area under the disease progress curve. Data for each observation date were plotted on a graph and the area under the line was calculated for each treatment providing a measure of the relative severity of disease throughout the season. A disease rating of 100% foliage infection for the entire season would produce a value of 1.0. All relative AUDPC values are expressed as the proportion of this value. Either decreased disease severity or later disease development will contribute to lower relative areas under the disease progress curve.

2 Applied: 7/27, 8/21, 9/1.

3 Applied: 7/19, 8/3, 8/21, 8/26, 9/1.

4 Applied: 7/12, 7/19, 7/27, 8/3, 8/11, 8/21, 8/26, 9/1.

5 Analysis of variance was performed on data, and Fisher's protected least significant difference (LSD) was calculated. NS = not significant at the $P = 0.05$ level.

Table 2. *Effect of cultivar or fungicide application on foliar blight development.*

Factor	Mean foliar blight [1] 7/19	8/3	8/10
Cultivar			
Heritage	0.6	1.7	5.5
Eclipse	0.7	1.4	6.2
Lucky B.	0.7	3.5	10.3
Convert	0.9	2.8	7.9
LSD ($P = 0.05$)	0.3*	0.6	1.6

1 There was a significant interaction between cultivar and fungicide for all rating dates after August 10 so it is inappropriate to consider cultivar or fungicide means for those data.

2 Applied: 7/27, 8/21, 9/1.

Factor	Mean foliar blight [1] 7/19	8/3	8/10
Fungicide			
Untreated Control	0.8	2.7	11.0
Bravo Ultrex, 1.4 lb/A, three week intervals (3 sprays) [2]	0.6	2.5	7.2
Bravo Ultrex, 1.4 lb/A, two week intervals (5 sprays) [3]	0.6	2.3	7.2
Bravo Ultrex, 1.4 lb/A, weekly (8 sprays) [4]	0.9	2.0	4.5
LSD ($P = 0.05$) [5]	0.3	0.6	1.6

3 Applied: 7/19, 8/3, 8/21, 8/26, 9/1.

4 Applied: 7/12, 7/19, 7/27, 8/3, 8/11, 8/21, 8/26, 9/1.

5 Analysis of variance was performed on data, and Fisher's protected least significant difference (LSD) was calculated. NS = not significant at the $P = 0.05$ level.

Table 3. Effect of treatment on carrot yield and size distribution and value.

Cultivar	Treatment schedule	Total Yield Tons/A [1]	Marketable Yield [2] Tons/A	Marketable Yield [2] %	Undersize %	Culls %	Cost of Chemicals per Acre [3]	Value of Yield Gross [4]	Value of Yield Net [5]	Effect of Treatment on Value [6]
Heritage	Untreated Control	13.6	12.6	91.3	2.4	6.3	0	655.71	655.71	0
	Bravo Ultrex, 1.4 lb/A, 3-week intervals (3 sprays) [7]	18.9	18.2	96.0	1.0	3.1	29.40	942.46	913.06	257.35
	Bravo Ultrex, 1.4 lb/A, 2-week intervals (5 sprays) [8]	18.8	17.4	92.5	1.9	5.6	49.00	914.20	865.20	209.49
	Bravo Ultrex, 1.4 lb/A, weekly (8 sprays) [9]	20.8	19.2	92.3	1.1	6.6	78.40	973.07	894.67	238.96
Eclipse	Untreated Control	14.4	13.0	88.4	2.2	9.4	0	637.52	637.52	0
	Bravo Ultrex, 1.4 lb/A, 3-week intervals (3 sprays) [7]	17.7	16.7	94.0	1.0	4.9	29.40	741.57	712.17	74.65
	Bravo Ultrex, 1.4 lb/A, 2-week intervals (5 sprays) [8]	16.7	14.9	89.3	1.0	9.7	49.00	651.32	602.32	-35.20
	Bravo Ultrex, 1.4 lb/A, weekly (8 sprays) [9]	17.0	14.9	87.4	0.9	11.7	78.40	692.10	613.70	-23.82
Lucky B	Untreated Control	17.8	16.7	93.4	4.6	1.9	0	910.01	910.01	0
	Bravo Ultrex, 1.4 lb/A, 3-week intervals (3 sprays) [7]	19.7	18.9	95.5	3.3	1.1	29.40	1019.43	990.03	80.02
	Bravo Ultrex, 1.4 lb/A, 2-week intervals (5 sprays) [8]	21.1	19.9	94.3	3.7	2.1	49.00	1075.33	1026.33	116.32
	Bravo Ultrex, 1.4 lb/A, weekly (8 sprays) [9]	20.4	19.1	93.7	3.3	3.0	78.40	1024.17	945.77	35.76
Convert	Untreated Control	16.4	6.4	38.7	58.1	3.1	0	279.38	279.38	0
	Bravo Ultrex, 1.4 lb/A, 3-week intervals (3 sprays) [7]	16.9	7.1	41.8	54.5	3.7	29.40	312.39	282.99	3.61
	Bravo Ultrex, 1.4 lb/A, 2-week intervals (5 sprays) [8]	17.7	8.0	45.1	52.3	2.7	49.00	349.76	300.76	21.38
	Bravo Ultrex, 1.4 lb/A, weekly (8 sprays) [9]	16.8	7.7	45.9	48.6	5.5	78.40	337.90	259.50	-19.88
LSD ($P = 0.05$) [10]		2.7	2.7	6.3	4.1	4.6	---	149.93	149.93	---

[1] Two 5-foot long sections across the planting bed were hand dug in each plot (equivalent to 20 feet of row) and yield was converted to tons/A. Yields may appear biased -- hand digging tends to result in a higher apparent yield as fewer carrots are lost than when mechanically dug.

[2] Marketable yield = carrots > ¾ in. diameter for slicers and > 1 1/4 in. diameter for dicers.

[3] Season-long cost of chemicals/Acre (rate, number of applications and retail cost are included in calculation). Retail price of Bravo Ultrex = $7.00/lb.

[4] Values are calculated based on typical 1995 processing contracts for uncrowned carrots. Minimum size for dicing contract is 1 1/4 inch.. Dicing price per ton is: >90% of crop over 2" diameter - $51.70; 81-90% > 2" - $51.30; 71-80% > 2" - $50.10; 61-70% > 2" - $48.00; 51-60% > 2" - $45.90; < 51% > 2" - $43.80. Minimum size accepted for slicing contract is 3/4 inch diameter. Slicing price per ton is: < 10% over 1 5/8" diameter - $52.50; 10-19% > 1 5/8" - $51.90; 20-29% > 1 5/8" - $50.65; 30-39% > 1 5/8" - $47.90; 40-49% > 1 5/8" - $45.20; >49% > 1 5/8" - $42.60.

[5] Gross yield minus the cost of fungicide applied.

[6] Net value of untreated control for each cultivar minus the net value of the specific treatment.

[7] Applied: 7/27, 8/21, 9/1.

[8] Applied: 7/19, 8/3, 8/21, 8/26, 9/1.

[9] Applied: 7/12, 7/19, 7/27, 8/3, 8/11, 8/21, 8/26, 9/1.

[10] Analysis of variance was performed on data, and Fisher's protected least significant difference (LSD) was calculated. NS = not significant at the $P = 0.05$ level.

Table 4. Effect of cultivar or fungicide treatment on carrot yield and size distribution and value.

Factor	Total Yield Tons/A [1]	Marketable Yield [2] Tons/A	Marketable Yield [2] %	Under-size %	Culls %
Cultivar					
Heritage	18.1	18.8	93.0	1.6	5.4
Eclipse	16.5	14.8	89.8	1.3	8.9
Lucky B	19.8	18.6	94.2	3.7	2.0
Convert	16.9	7.3	42.9	53.4	3.7
LSD ($P = 0.05$) [3]	1.3	1.4	3.1	2.1	2.3
Fungicide					
Untreated Control	15.6	12.2	78.0	16.8	5.2
Bravo Ultrex, 1.4 lb/A, 3-week intervals (3 sprays) [4]	18.3	15.2	81.8	15.0	3.2
Bravo Ultrex, 1.4 lb/A, 2-week intervals (5 sprays) [5]	18.6	15.0	80.3	14.7	5.0
Bravo Ultrex, 1.4 lb/A, weekly (8 sprays) [6]	18.7	15.2	79.8	13.5	6.7
LSD ($P = 0.05$) [3]	1.3	1.4	NS	2.1	2.3

1 Two 5-foot long sections across the planting bed were hand dug in each plot (equivalent to 20 feet of row) and yield was converted to tons/A. Yields may appear biased -- hand digging tends to result in a higher apparent yield as fewer carrots are lost than when mechanically dug.
2 Marketable yield = carrots > ¾ in. diameter for slicers and > 1 1/4 in. diameter for dicers.
3 Analysis of variance was performed on data, and Fisher's protected least significant difference (LSD) was calculated. NS = not significant at the $P = 0.05$ level.
4 Applied: 7/27, 8/21, 9/1.
5 Applied: 7/19, 8/3, 8/21, 8/26, 9/1.
6 Applied: 7/12, 7/19, 7/27, 8/3, 8/11, 8/21, 8/26, 9/1.

Table 5. Effect of treatment on carrot yield and size distribution - Slicer types.

Cultivar	Treatment schedule	Total Yield Ton/A [1]	Yield for carrot diameter (inches) < 3/4 Ton/A	%	3/4 - 1 1/4 Ton/A	%	1 1/4 - 1 ¾ Ton/A	%	> 1 3/4 Ton/A	%	Culls Ton/A	%
Heritage	Untreated Control	13.6	0.3	2.4	8.2	60.9	4.1	26.3	0.3	4.1	0.8	6.3
	Bravo Ultrex, 1.4 lb/A, 3-week intervals (3 sprays) [2]	18.9	0.2	1.0	9.6	50.4	8.4	44.5	0.2	1.1	0.6	3.1
	Bravo Ultrex, 1.4 lb/A, 2-week intervals (5 sprays) [3]	18.8	0.4	1.9	8.2	43.8	9.0	47.9	0.1	0.7	1.1	5.6
	Bravo Ultrex, 1.4 lb/A, weekly (8 sprays) [4]	20.8	0.2	1.1	9.4	45.0	9.1	44.1	0.7	3.2	1.4	6.6
Eclipse	Untreated Control	14.4	0.3	2.2	5.3	37.3	6.8	46.0	0.8	5.1	1.1	9.4
	Bravo Ultrex, 1.4 lb/A, 3-week intervals (3 sprays) [2]	17.7	0.2	1.0	5.6	31.7	8.9	50.2	2.1	12.2	0.9	4.9
	Bravo Ultrex, 1.4 lb/A, 2-week intervals (5 sprays) [3]	16.7	0.2	1.0	4.7	28.0	8.0	47.9	2.2	13.3	1.6	9.7
	Bravo Ultrex, 1.4 lb/A, weekly (8 sprays) [4]	17.0	0.2	0.9	5.4	31.3	8.0	47.7	1.5	8.4	2.0	11.7
Lucky B	Untreated Control	17.8	0.8	4.6	13.1	73.8	3.5	19.3	0.1	0.3	0.3	1.9
	Bravo Ultrex, 1.4 lb/A, 3-week intervals (3 sprays) [2]	19.7	0.7	3.3	13.6	68.9	5.2	26.7	0.0	0.0	0.2	1.1
	Bravo Ultrex, 1.4 lb/A, 2-week intervals (5 sprays) [3]	21.1	0.8	3.7	14.3	67.8	5.5	26.2	0.1	0.3	0.4	2.1
	Bravo Ultrex, 1.4 lb/A, weekly (8 sprays) [4]	20.4	0.7	3.3	12.7	62.6	6.2	30.5	0.1	0.6	0.6	3.0
LSD ($P = 0.05$) [5]		3.1	0.3	1.4	2.3	7.8	1.9	10.6	0.9	6.1	0.7	5.0

1 Two 5-foot long sections across the planting bed were hand dug in each plot (equivalent to 20 feet of row) and yield was converted to tons/A. Yields may appear biased -- hand digging tends to result in a higher apparent yield as fewer carrots are lost than when mechanically dug.
2 Applied: 7/27, 8/21, 9/1.
3 Applied: 7/19, 8/3, 8/21, 8/26, 9/1.
4 Applied: 7/12, 7/19, 7/27, 8/3, 8/11, 8/21, 8/26, 9/1.
5 Analysis of variance was performed on data, and Fisher's protected least significant difference (LSD) was calculated. NS = not significant at the $P = 0.05$ level.

Table 6. Effect of cultivar or fungicide application on carrot yield and size distribution - Slicer types.

Factor	Total Yield (Ton/A) [1]	Carrot Diameter (inches) < 3/4 Yield (Ton/A)	< 3/4 %	3/4 - 1 5/8 Yield (Ton/A)	3/4 - 1 5/8 %	1 5/8 - 2 Yield (Ton/A)	1 5/8 - 2 %	> 2 inch Yield (Ton/A)	> 2 inch %	Culls Yield (Ton/A)	Culls %
Cultivar											
Heritage	18.1	0.3	1.6	8.8	50.0	7.7	40.7	0.3	2.3	1.0	5.4
Eclipse	16.5	0.2	1.3	5.2	32.1	7.9	48.0	1.7	9.8	1.4	8.9
Lucky B	19.8	0.7	3.7	13.4	68.3	5.1	25.7	0.1	0.3	0.4	2.0
LSD ($P = 0.05$) [2]	1.5	0.1	0.7	1.2	3.9	1.0	5.3	0.4	3.1	0.4	2.5
Fungicide											
Untreated Control	15.3	0.5	3.1	8.9	57.6	4.8	30.5	0.4	3.2	0.7	5.9
Bravo Ultrex, 1.4 lb/A, 3-week intervals (3 sprays) [3]	18.8	0.3	1.8	9.6	50.	7.5	40.4	0.8	4.4	0.6	3.1
Bravo Ultrex, 1.4 lb/A, 2-week intervals (5 sprays) [4]	18.9	0.4	2.2	9.1	46.6	7.5	40.7	0.8	4.8	1.1	5.8
Bravo Ultrex, 1.4 lb/A, weekly (8 sprays) [5]	19.4	0.3	1.7	9.2	46.3	7.8	40.8	0.8	4.1	1.3	7.1
LSD ($P = 0.05$) [2]	1.8	NS	0.8	NS	4.5	1.1	6.1	NS	NS	0.4	2.9

1 Two 5-foot long sections across the planting bed were hand dug in each plot (equivalent to 20 feet of row) and yield was converted to tons/A. Yields may appear biased – hand digging tends to result in a higher apparent yield as fewer carrots are lost than when mechanically dug.

2 Analysis of variance was performed on data, and Fisher's protected least significant difference (LSD) was calculated. NS = not significant at the $P = 0.05$ level.

3 Applied: 7/27, 8/21, 9/1.

4 Applied: 7/19, 8/3, 8/21, 8/26, 9/1.

5 Applied: 7/12, 7/19, 7/27, 8/3, 8/11, 8/21, 8/26, 9/1.

Table 7. Effect of treatment on carrot yield and size distribution - Dicer types.

Cultivar	Treatment schedule	Total Yield Ton/A [1]	Yield for carrot diameter (inches)							
			< 1 1/2		1 1/2 - 2		> 2		Culls	
			Ton/A	%	Ton/A	%	Ton/A	%	Ton/A	%
Convert	Untreated Control	16.4	11.4	70.0	4.1	24.7	0.4	2.1	0.5	3.1
	Bravo Ultrex, 1.4 lb/A, 3-week intervals (3 sprays) [2]	16.9	11.1	65.7	4.9	29.0	0.3	1.6	0.6	3.7
	Bravo Ultrex, 1.4 lb/A, 2-week intervals (5 sprays) [3]	17.7	11.2	63.0	5.4	30.5	0.7	3.8	0.5	2.7
	Bravo Ultrex, 1.4 lb/A, weekly (8 sprays) [4]	16.8	9.8	58.6	5.3	31.6	0.7	4.4	0.9	5.5
LSD ($P = 0.05$) [5]		NS	NS	NS	NS	NS	NS	NS	NS	NS

1 Two 5-foot long sections across the planting bed were hand dug in each plot (equivalent to 20 feet of row) and yield was converted to tons/A. Yields may appear biased -- hand digging tends to result in a higher apparent yield as fewer carrots are lost than when mechanically dug.

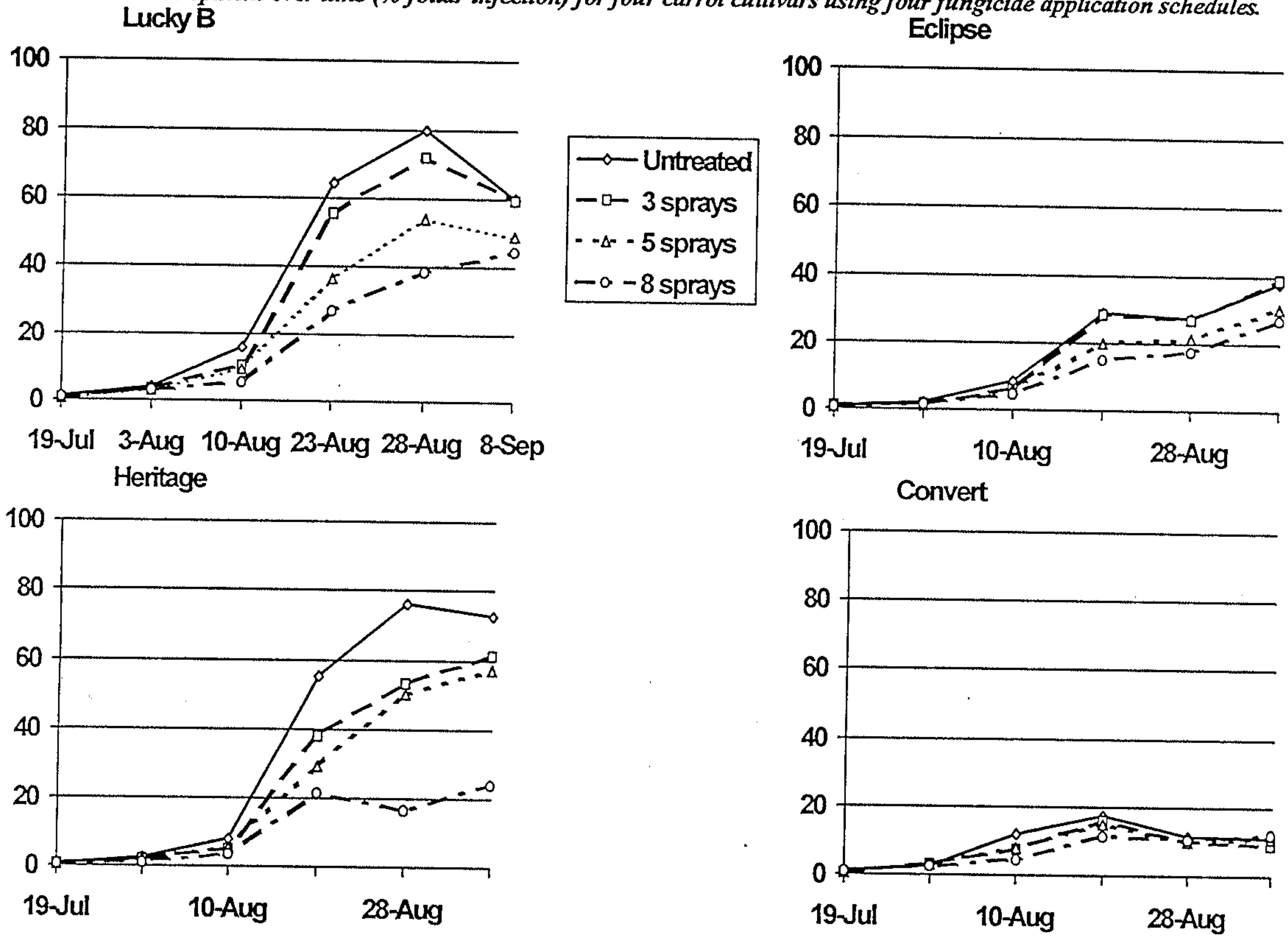
2 Applied: 7/27, 8/21, 9/1.

3 Applied: 7/19, 8/3, 8/21, 8/26, 9/1.

4 Applied: 7/12, 7/19, 7/27, 8/3, 8/11, 8/21, 8/26, 9/1.

5 Analysis of variance was performed on data, and Fisher's protected least significant difference (LSD) was calculated.
NS = not significant at the $P = 0.05$ level.

Fig 1. Disease development over time (% foliar infection) for four carrot cultivars using four fungicide application schedules.



LSD ($P = 0.05$) : Jul 19 - NS; Aug 3 - 1.1; Aug 10 - 3.2; Aug 23 - 9.7; Aug 28 - 10.7; Sep 8 - 13.3 (applies to all graphs on this page)

Fig 2. ***Relative area under the disease progress curve for four carrot cultivars using four fungicide application schedules.***

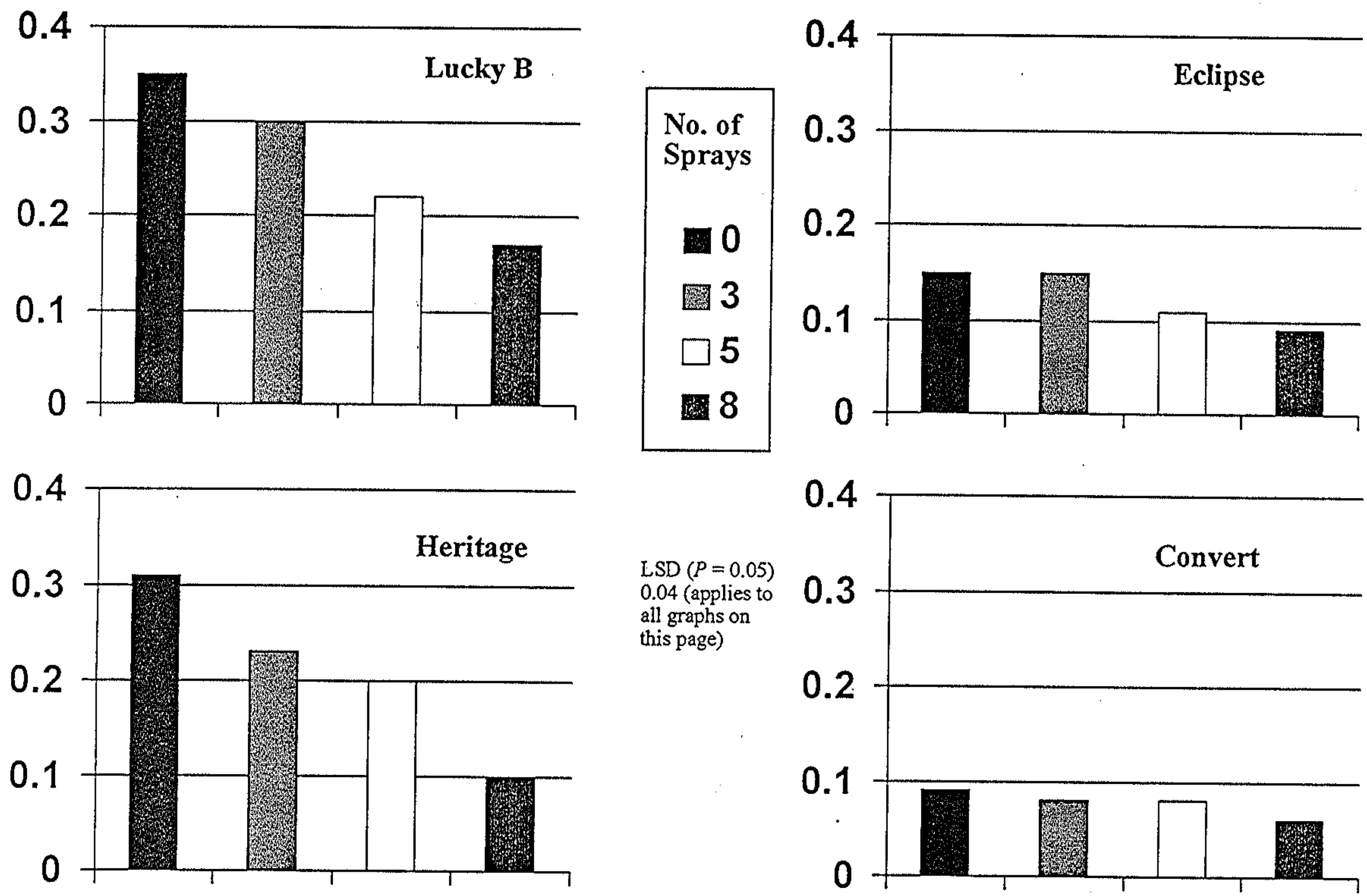
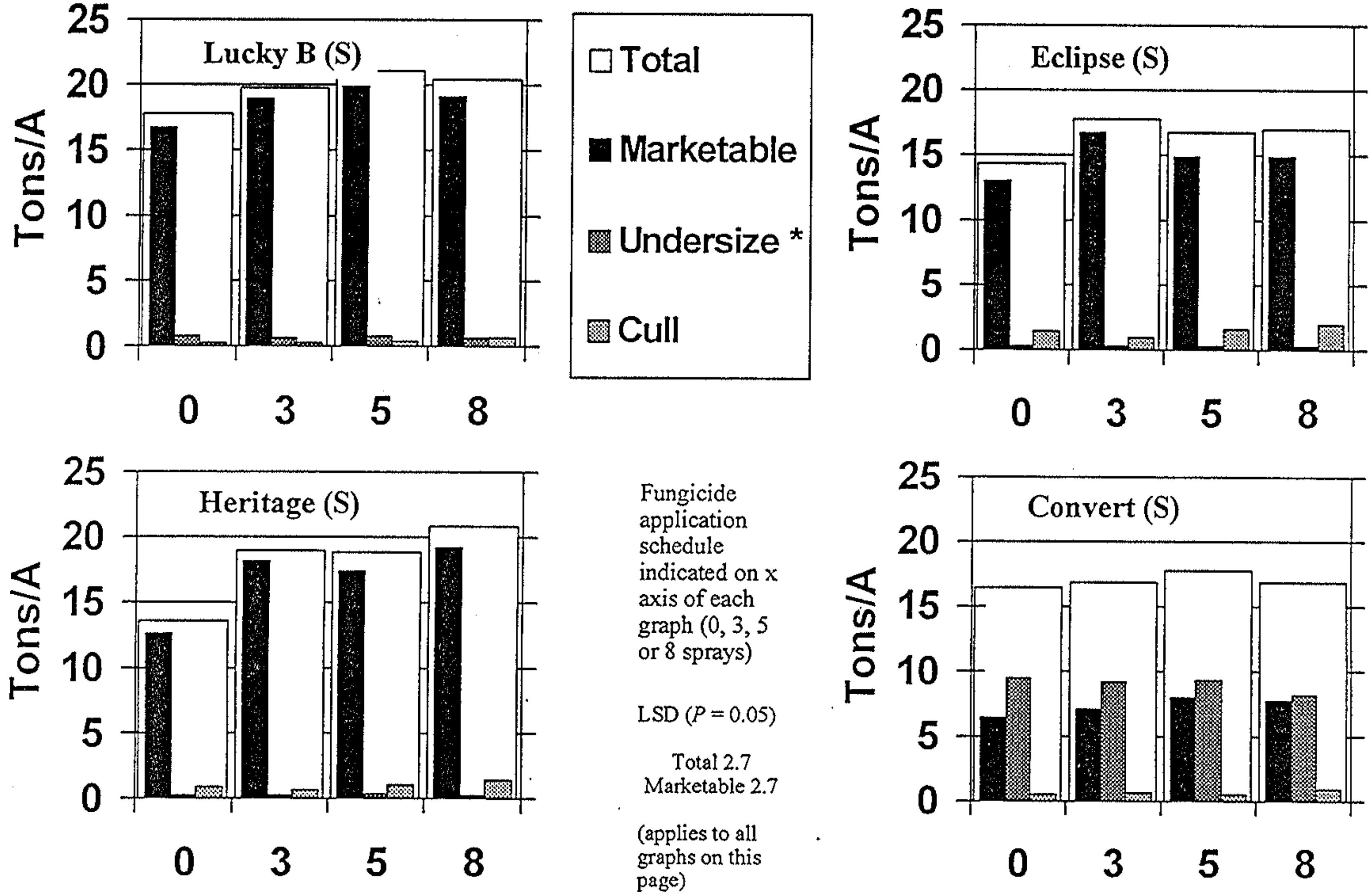
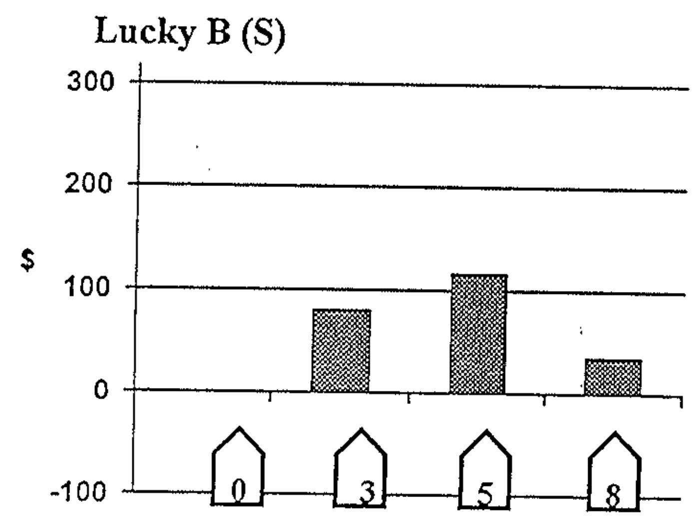


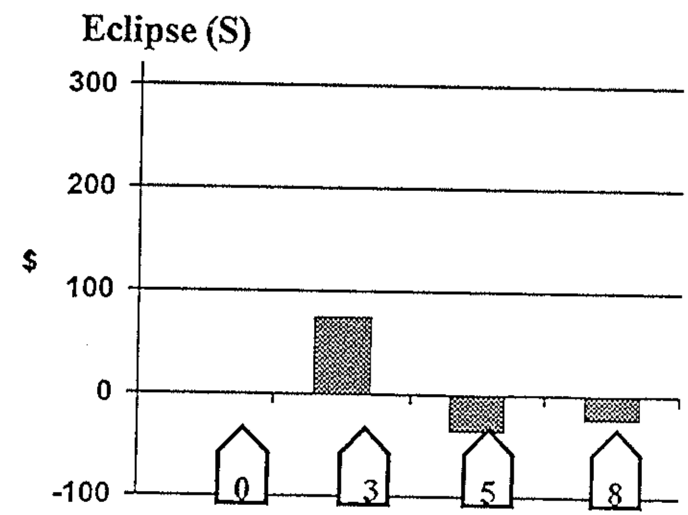
Fig 3. *Yield (total, marketable, undersize and cull) for four carrot cultivars using four fungicide application schedules.*



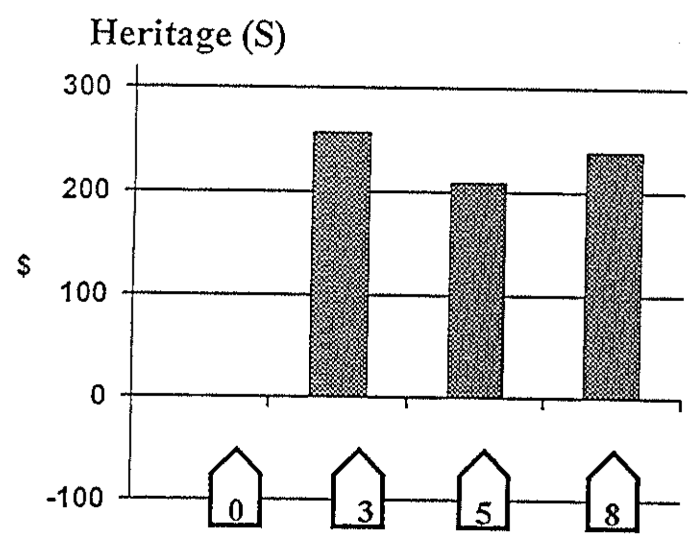
* S = graded as a slicer, marketable yield is anything > 3/4 inch. D = graded as a dicer, marketable yield is anything > 1 1/4 inch.

Fig 4. Relative value of fungicide treatment compared to untreated control for four carrot cultivars.

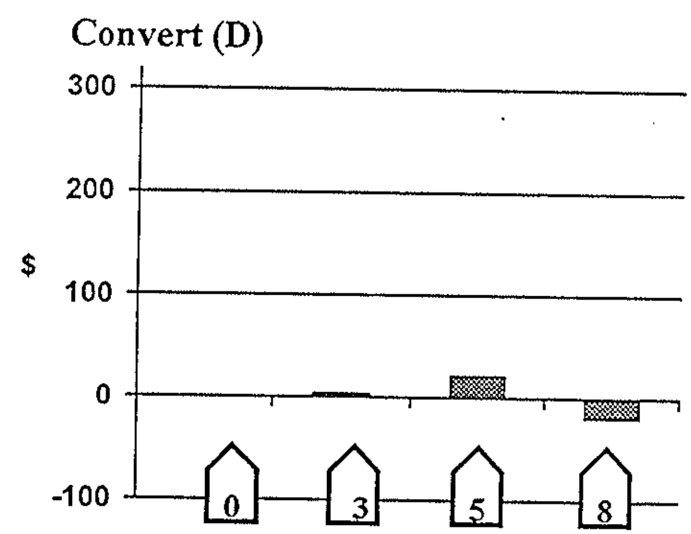




Cultivar	Value of untreated control (used as base for value calculation) Dicer	Slicer
Lucky B	---	$ 910
Eclipse	---	$ 638
Heritage	---	$ 656
Convert	$ 279	---



Fungicide application schedule indicated by arrows on each graph (0, 3, 5 or 8 sprays)



Profile Of Carrot Production In Wisconsin
6/1/92

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Carrots represent an important vegetable crop to the State of Wisconsin. The Wisconsin carrot crop is grown on approximately 4,000 acres for an average crop value of approximately $2,700 per acre (Table 1). The crop is grown primarily on muck soil, although in the past two years, acreage on irrigated loamy sand in central and southern Wisconsin has increased. Most of the acreage is grown for processing, slicing and dicing carrots, although one producer in southeast Wisconsin grows a sizeable acreage for fresh market consumption.

Table 1. Wisconsin carrot acreage, yield, production and value, 1987-90.

	Planted Acres	Harvested Acres	Yield/A CWT	Production 1,000 CWT	Value ($/A)
1990 -	4,200	4,000	445	1,780	$2,895
1989 -	3,900	3,300	475	1,568	2,583
1988 -	4,100	3,200	405	1,296	2,393
1987 -	3,800	3,500	500	1,750	3,001

Crop Specifics

A range of carrot cultivars is grown in Wisconsin to meet processing and fresh market demands. Currently the cultivars PY60 and Prospector are grown for processed slicing carrots, Gold King and Danvers are grown for processed dicing carrots and 6-Pak, Prospector, Orlando Gold and 6-Pence are grown as fresh market carrots. These seem to be some of the more popular cultivars at this time, but there are many more cultivars than those listed that are available and planted by many of the growers.

Carrots are grown to meet specific processing and marketing needs. Thus planting stretches over a broad time period. First plantings are made on about April 10 and the planting period often proceeds to as late as July 10. The early planted fields are often the first to be harvested and harvest can occur as early as mid-July. The harvesting operation may extend to mid-November depending on processor needs, fresh markets and weather.

Most of the processing carrots are crowned in the field. The crowning operation consists of using a field chopper to remove the foliage and crowns in the field just prior to harvest. Crowning is not a precision operation due to variation in the height and orientation of carrots in the row. Growers generally feel that they achieve a crowning accuracy of 60-100% in any given field. The harvester then lifts the crowned carrots from the field and moves them to a waiting vehicle for transport to the processing plant. In the future, the need for field crowning may decline as processors install new color/blemish sorters in the processing plants. These sorters could then automatically remove any carrot slice or cube with inferior color or a blemish from the processing line. There would then be less reliance on the field crowning aspect of production. Fresh market carrots are not crowned at harvest and the foliage plays an integral part in harvest as the plants are pulled by the foliage into the harvester.

Processing carrots are washed thoroughly upon entering the processing plant. Depending on the processor, the carrots are then peeled with pressurized steam or hot lye. The surface of the carrot root is then brushed to remove soft debris and washed several times before further slicing and dicing. These preliminary steps in the processing operations would in effect remove residues of pesticides adhering to the surface tissues of the root. Fresh market carrots are topped in the packing shed and washed thoroughly before being placed in shipping containers for market.

Pest Control

Aster yellows is caused by a mycoplasma transmitted by the aster leafhopper. This disease is a major threat to production because of yield and quality reductions associated with infected carrots. Thus carrot acreage is treated with multiple applications of insecticides according to IPM scouting recommendations. The insecticides Sevin, Asana, Lannate and Diazinon are used to control the aster leafhopper and associated transmission of the aster yellows mycoplasma.

Weed control is essential, especially on young carrots before a crop canopy is established. The herbicides Fusilade, Sencor and Lorox are used by the industry to control grass and broadleaf weeds.

Alternaria and Cercospora leaf blights are observed on most fields at some time during the growing season. Weather conditions help determine the appearance of both of these fungal incited diseases and subsequent spread through the field. Both diseases attack the foliage and gradually debilitate the affected plants. Yields of affected plantings are reduced (estimated up to 25%) and premature defoliation affects plant vigor and root quality. Cercospora leaf blight is especially serious on fresh market carrots since it attacks and weakens the petioles. Healthy petioles are important in the harvest of fresh market carrots since the harvester grasps onto the foliage and pulls the carrots from the ground. Breakage of petioles at harvest due to extensive Cercospora infection interferes with harvest and badly infected carrots are left in the field because they cannot be harvested with existing machinery. Major breeding efforts are underway to develop carrot cultivars with both fresh market and processing qualities along with a high level of resistance to both Alternaria and Cercospora leaf blights. Widescale use of improved cultivars with blight resistance is probably several years away.

In lieu of acceptable cultivars with resistance to leaf blights, Wisconsin growers treat carrot acreage with multiple applications of fungicide beginning when the first plantings have reached the 6 to 9" stage in mid-June and the first symptoms of disease are beginning to appear. Fungicide sprays continue at 7-14 day intervals depending on IPM scouting reports and weather conditions. Fields may be treated with fungicide 5-10 times during the normal growing season. The fields planted last are treated through mid-October for a total of 5-10 sprays. Fresh market carrots are treated with 1-10 sprays, with the fewest sprays applied to the early planted and early harvested fields and the greatest number of sprays applied to the fields harvested late in the growing season.

Fungicide Spray Programs For Disease Control

The number of fungicides available to the Wisconsin carrot grower for disease control is increasingly limited (Tables 2 & 3). Through 1990, growers were able to use mancozeb and TPTH fungicides for control of Alternaria and Cercospora leaf blights. Currently growers can use only fixed coppers, chlorothalonil and iprodione. Each of these materials has its own limitations including low efficacy, high cost (Table 4), limits on the number of applications, plantback restrictions or narrow spectrum of control activity. A comparison of the chemical costs for treating carrots with various brands of fungicide demonstrates a wide discrepancy in costs. Table 5 compares chemical costs when the various materials are used at full label rate one or more times during the growing season. Table 6 compares chemical costs for Bravo 720 and Penncozeb 75DF when each of these materials is used at the lowest label rates early in the season and the full label rates late in the season. The latter would be considered to be a typical use pattern where growers want to minimize the total amount of fungicide used during the season and the total cost of the chemicals purchased. Both programs would be expected to provide a similar level of control, although the control costs are clearly very different.

Table 2. Products currently registered for use on carrots.

Common name	Brand Name	Rate	PHI	Comments
Fixed coppers	Kocide 101	2 lb	0 days	Low efficacy
chlorothalonil	Bravo 720 Bravo 90DG	1.5-2 pt 1.25-1.5 lb	0 days	Effective, high cost, current plant-back restrictions are expected to be resolved soon
iprodione	Rovral 4F	1-2 pt	0 days	Controls only Alternaria leaf blight and not Cercospora leaf blight, very expensive, limit of 4 applications per growing season

Application of fungicides on carrots in Wisconsin utilizes both aerial and ground equipment, although ground equipment is used by a majority of growers. Costs of aerial application are in the $4.00 to $5.00/A range, while the costs for ground equipment vary from approximately $2.00 to $5.00/A. The $5.00/A estimate for application appears to be an average cost above the cost of the chemical chosen by the grower for disease control.

Table 3. Products historically, but not currently, labeled for use on carrots.

Common name	Brand Name	Rate	PHI	Comments
mancozeb	Mancozeb 80WP	1.5-2 lb	7 days	Effective
	Manzate 200 DF	1.5-2 lb	7 days	Effective
	Dithane 75DF	1.5-2 lb	7 days	Effective
	Penncozeb 75DF	1.5-2 lb	7 days	Effective
triphenyltin hydroxide	Super Tin 4L	4-8 fl oz	14 days	Limit to 6 treatments per growing season

Table 4. Current market costs of fungicides.

Brand Name	Current price
Bravo 720	$43.00/gal
Bravo 90DG	$6.95/lb
Dithane M45 80WP	$2.05/lb
Manzate 200 DF	$2.05/lb
Kocide 101	$2.14/lb
Mancozeb 80WP	$1.70/lb
Penncozeb 75DF	$2.00/lb
Rovral 4F	$120.00/gal
Super Tin	$97.94/gal

Table 5. Cost comparisons for fungicide treatment programs (excluding the cost of commercial application).

		Number of Applications			
Brand Name	Rate	1	4	7	9
Bravo 720	2 pt/A	$10.75	$43.00	$75.25	$96.75
Bravo 90DG	1.5 lb/A	$10.43	$41.72	$73.01	$93.87
Dithane M45 80WP	2 lb/A	$4.10	$16.40	$28.70	$36.90
Kocide 101	2 lb/A	$4.28	$17.12	$29.96	$38.52
Mancozeb 80WP	2 lb/A	$3.40	$13.60	$23.80	$30.60
Manzate 200 DF	2 lb/A	$4.10	$16.40	$28.70	$36.90
Penncozeb 75DF	2 lb/A	$4.00	$16.00	$28.00	$36.00
Rovral 4F	2 pt/A	$30.00	$120.00	NA	NA

Table 6. Comparison of chemical costs for typical Bravo and Penncozeb spray programs that use the lowest label rates for the first four applications and the highest label rates for the last five applications.

Brand Name	Schedule and rate of application	Chemical Cost
Bravo 720	First 4 applications at 1.5 pt/A	$32.25/A
	Next 5 applications at 2.0 pt/A	$53.75/A
	Total chemical cost =	$86.00/A
Penncozeb 75DF	First 4 applications at 1.5 lb/A	$12.00/A
	Next 5 applications at 2.0 lb/A	$20.00/A
	Total chemical cost =	$32.00/A

Proposed Changes In The Mancozeb Label

Representatives of the Wisconsin carrot industry met with Dr. William Spencer, Marketing Manager, Atochem North America, Inc. on March 31, 1992 for the purpose of reaching a consensus regarding future registration of mancozeb on carrots. All growers in attendance stressed the importance of a carrot registration for mancozeb. They stressed the long history of safe mancozeb use for disease control on carrots. They also stressed that, as an industry, they were willing to make certain concessions to insure a future registration of mancozeb on carrots. These concessions include a cap on the amount of product used per acre during a growing season (14 lb/A of a 75% DF formulation per season) and an extension of the pre-1989 label's 7-day preharvest interval to a 14-day preharvest interval. Most growers already practice a 14-day preharvest interval and many fields are already treated with less than 14 lb of formulated product per acre during the growing season. The Wisconsin carrot growers reached consensus that the attached label would allow them to effectively combat foliar blights on carrot and to safely use mancozeb fungicides on their farm. The label is attached for your careful review. This label is very similar to the labels already adopted by the EPA that allow continued use of EBDC products to control foliar blights on potato.

These same growers also pledged their support for field research that would demonstrate the value of this label in minimizing the potential for EBDC and ETU residues in the fresh and processed carrot product. Pending the arrival of GLP's from the EBDC Task Force for evaluating this label under field conditions, we are actively planning summer field trials on carrots using a mancozeb fungicide as the fungicide program. Any advice or encouragement you or your Task Force could provide would be gratefully received. We do need to initiate these trials in the next 3 weeks so time is of the essence.

Proposed Label For Mancozeb Use On Carrots (3/31/92)

Mancozeb 75DF

Disease/Pest	Application Rate	Timing of Sprays	Comments	Last Application To Harvest
Alternaria leaf spot Cercospora leaf spot	1 to 2 Lb/A	Plant the most disease tolerant varieties compatible with marketing needs. Use an Integrated Pest Management that carefully evaluates crop health to determine the need for and timing of fungicide applications. Use lower rates of fungicide at the beginning of the spray program and adjust the rates of application according to need. Thorough coverage of all carrot foliage with fungicide is essential to good disease control and crop protection.	Do not enter treated areas without appropriate protective clothing such as long pants, shoes and socks until sprays have dried. After sprays have dried, do not enter or allow entry into treated areas until a 24-hour re-entry interval has expired unless wearing appropriate protective clothing. During mixing and loading, a long-sleeved shirt and long pants or a coverall that covers all parts of the body except head, hands and feet, chemical resistant gloves, shoes, socks and goggles or a face shield and a chemical resistant apron must be worn .	Do not apply Mancozeb DF within 14 days of harvest. Do not apply more than 14 lbs (product) per acre per season.

Summary

EBDC fungicides in the form of mancozeb have been used for almost four decades to protect the carrot crop from foliar blights incited by fungal pathogens. Loss of the EBDC label on carrots has drastically increased the cost of disease control. These added production costs are generally absorbed by the grower and not passed on to the consumer in terms of market price. The growers recognize the need to produce carrots using the safest possible production practices and to provide carrots to the consumer that are free of pesticide residues. To this end, a new mancozeb label is attached that sets a limit on the amount of formulated mancozeb product allowed per acre per growing season and extends the pre-harvest interval from 7 to 14 days. The growers also propose to test the validity of this label in terms of impact on EBDC and ETU residues through field trials to be conducted during the summer of 1992. Guidelines and protocols for conducting these trials are anticipated from the EBDC Task Force in the near future. Trials will be initiated shortly after receipt of this information.