Leaf Spot Control, Maneb, and Ethylenethiourea Residues in Processed Turnip Greens Treated with Maneb

DONALD R. SUMNER and DURHAM K. BELL, University of Georgia, Department of Plant Pathology, Coastal Plain Experiment Station, Tifton 31793-0748; DORRIS A. LILLARD and WILLIAM C. HURST, Department of Food Science, and PARSHALL A. BUSH, Department of Poultry Science, Athens 30602; and T. B. BRENNEMAN, Department of Plant Pathology, Coastal Plain Experiment Station, Tifton 31793-0748

ABSTRACT

Sumner, D. R., Bell, D. K., Lillard, D. A., Hurst, W. C., Bush, P. A., and Brenneman, T. B. 1991. Leaf spot control, maneb, and ethylenethiourea residues in processed turnip greens treated with maneb. Plant Dis. 75:878-882.

Turnip leafy greens were grown in the spring and fall for processing into frozen greens. Maneb + zinc (1.8 or 0.9 kg a.i./ha), benomyl, chlorothalonil, or iprodione were applied weekly until 10 days before greens were harvested. Greens either sprayed with maneb + zinc or not sprayed were processed by washing with water (pH 6.7–6.9), 0.1% detergent (pH 6.7–6.9), or alkaline detergent (pH 9.7–9.9). All fungicide treatments reduced foliage disease induced by *Pseudocercosporella capsellae*. Reflectance data with a multispectral radiometer indicated no differences among fungicide treatments, and reflectance was negatively correlated with visual disease ratings and positively correlated with the percentage of leafy greens acceptable for processing. All methods of washing leafy greens sprayed with 1.8 or 0.9 kg a.i./ha of maneb + zinc reduced maneb but not ethylenethiourea (ETU) levels compared with unwashed greens. Cooking reduced maneb but not ETU levels compared with raw greens. There were no differences in ETU residues in greens between the two application rates of maneb + zinc. ETU residues were usually below 0.1 ppm in cooked greens in all treatments.

Numerous fungi are pathogenic on foliage of turnip (*Brassica rapa* L.), mustard (*B. juncea* (L.) Czernj & J. M. Coulter var. *crispifolia* L. H. Bailey), and kale (*B. oleracea* L. var *acephala* DC.) grown for leafy greens (4,5,18,21,22). The fungi and the diseases they cause include *Cercospora brassicicola* Henn. (Cercospora leaf spot), *Pseudocercosporella capsellae* (Ellis & Everh.) Deighton (= *Cercosporella brassicae* (Fautrey & Roum.) Höhn.) (pale or white leaf spot), *Colletotrichum higginsianum* Sacc. in Higgins (anthracnose), *Peronospora parasitica* (Pers.:Fr.) Fr. (downy mildew), and *Alternaria brassicicola* (Schwein.) Wiltshire (Alternaria leaf spot). Leaf spots cause discoloration and decay of the leaf petioles and blades. Leaves with more than 10% of the surface area discolored are nonsalable according to U.S. Department of Agriculture standards for mustard and turnip greens (23). Most leafy greens are harvested mechanically by once-over cutting, but all foliage is removed, and hand separation of unacceptable leaves and decayed tissue is time-consuming, difficult, and expensive.

In 1987, there were an estimated 6,800 ha of greens (collards, kale, turnips, and mustard) in Georgia (11) with a farm value in excess of $16 million. In the United States, 30,000,000 kg of frozen greens and 50,000,000 kg of fresh greens were produced in 1988 (24). Data on production of canned greens are not available. Annual consumption of all fresh-market leafy, green and yellow vegetables has steadily increased from 14 to 17 kg per capita in the United States from 1970 to 1984. Turnip greens and turnip greens with turnip roots comprised 17,600,000 kg (59%) of all frozen greens (not including spinach) produced in the United States in 1988.

Maneb + zinc (but not mancozeb) was registered for use on leafy greens in Georgia through 1990. Benomyl is registered on turnip but does not control Alternaria leaf spot and downy mildew on turnip. The label for chlorothalonil has not been expanded to include disease control on leafy greens (including spinach), and iprodione is not labeled on leafy greens.

Earlier research in Georgia showed that weekly applications of maneb + zinc at 1.8 kg a.i./ha initiated 2 wk after planting and 2–3 days after each cutting gave good protection against foliage pathogens in turnip grown for leafy greens (21). However, lower rates were not tested for efficacy, and there was no attempt to determine the influence of washing (as done in processed greens) on residues of ethylenethiourea (ETU) or maneb in leafy greens. A tolerance of 10 ppm of maneb in turnip greens has been established by the Environmental Protection Agency (6), but no tolerance has been set for ETU. Attention has recently been focused on ETU because it not only increased in home cooking and processing (12,13), but it has also been reported to be a potent teratogen and tumorigen in rats (10,17) and is considered a potential risk to human health.

Studies of fungicide efficacy against foliage pathogens of leafy greens should be augmented by a technique that models the progression of disease without destructive sampling for quality evaluation. Multispectral radiometers that record radiation in the visible and near infrared regions of the electromagnetic spectrum (0.3–1.4 μm) could provide an alternative to other disease assessment methods. Numerous studies have used this technique to measure radiation reflected from crop canopies and effectively quantify differences in stand densities (1) and foliar disease development (19) in cereals. Working with peanut, Almihana (2) found that percent reflectance of 800-nm wavelength radiation was strongly correlated with dry weight, leaf area index, and incidence of foliar disease. Reflectance data provided the best estimation of yield when all parameters were compared because of its objective analysis of the amount of green leaf area present. Multispectral radiometers have recently been shown to be useful for evaluating the efficacy of fungicides for control of foliar peanut diseases (14).

If growers do not use a fungicide to protect leafy greens against leaf spot pathogens, it may no longer be profitable for growers to produce leafy greens and for processors to freeze or can them. This research was done in support of a multimillion dollar industry that supplies greens that are an important part of the daily diet for the population of the United States.

MATERIALS AND METHODS

Spring crop. Turnip was grown on Tifton and Dothan loamy sand (fine-loamy, siliceous, thermic, Plinthic Paleudult) under overhead sprinkler irrigation at the Coastal Plain Station. Four rows of the cultivar All Top A04W were planted on 1 March 1988 on raised beds 1.8 m wide. A randomized complete block design with four replications of six treatments (Table 1) was used. Plots were

Accepted for publication 1 March 1991 (submitted for electronic processing).

one bed wide and 9.1 m long with a 3-m alley between blocks and an unsprayed border bed between plots. Treatments were applied in 468 L of water per hectare with a tractor-mounted boom sprayer with four nozzles (Teejet flat spray tip No. 8006) spaced 46 cm apart, at 3.5 kg/ cm^2 pressure, on 29 March and 6, 14, and 22 April. Control plots were not sprayed.

Turnips were rated for leaf spot severity on 13, 19, and 29 April and 2 May. Ten days after the last fungicide application, the center 1.5 m of the middle two rows was harvested by hand. Leaves were graded by hand as acceptable for processing (less than 10% of the surface area decayed by leaf spots) or unacceptable. Leaves were harvested from the remainder of the middle two rows (to within 0.6 m of the edge of each plot) for analysis of maneb and ETU residues in the control and treatments receiving 0.9 and 1.8 kg a.i./ha of maneb + zinc. Samples were packed into plastic bags with ice and transported immediately to the Food Science Department in Athens, GA (4-hr drive), for processing.

First fall crop. The same methods and experimental design were used for the fall crop of turnip. Turnip was planted on 30 August 1988 and sprays were applied on 15, 22, and 30 September. Leaf spots in the two middle rows of each plot were counted on 21, 26, and 30 September, and the percentage of foliage discoloration and decay was estimated on 5 October. Percent reflectance of sunlight from turnip canopies was recorded on 6 October in the 800 ± 13 nm range with a multispectral radiometer (CROPSCAN, Inc., Fargo, ND). Reflectance values were recorded from the center of each plot with the radiometer sensor positioned approximately 2 m above the turnip canopy. Product moment (Pearson) correlations were determined to study the relationship between reflectance values; visual disease ratings (30 September) and percent discoloration and decay ratings (5 October); and total weight, unacceptable weight, and acceptable weight of leafy greens (10 October). Leafy greens were harvested and graded on 10 October, and samples for residues were packed with ice and transported to Athens.

Second fall crop. After harvest of the 1988 fall crop, 224 kg/ha of ammonium nitrate was applied over the stubble, and the field was irrigated with 1.3 cm of water. Fungicide treatments were continued in the same plots as in the first crop without rerandomization. Treatments were applied on 13, 20, and 27 October. The greens were sprayed with soluble boron (0.28 kg/ha) on 18 October and magnesium sulfate (4.48 kg/ha) on 19 October to prevent boron and magnesium deficiencies. The percentage of foliage discoloration and decay was estimated on 31 October and 14 November. Greens were not harvested because the foliage in all treatments was considered nonsalable on 14 November.

Processing. Freshly harvested turnip greens were received at the Food Science Department, Athens, on 2 May and 10 October 1988. After overnight cold storage, greens were processed in a manner that simulated commercial processing operations. Four sets of 0.9 kg of unwashed green samples were collected at random from the control and each chemical treatment for maneb and ETU residue analyses. Remaining greens (control and treated) were divided into three lots and processed in three washing solutions (tap water, 0.1% Duponol WAQ, and alkaline 0.1% Duponol WAQ). Duponol WAQ (E. I. du Pont de Nemours & Company, Wilmington, DE) has been used by some processors to remove aphids from leafy greens. When added at a rate of 0.1% to the wash solution, the pH (6.7–6.9) did not differ significantly from tap water. However, EBDC is unstable under alkaline conditions (7), so a 0.1% Duponol solution was adjusted to pH 9.7–9.9 with 0.1 N NaOH. Greens were then spray rinsed for 2 min followed by a 3-min agitation in each wash solution in a 237-L stainless steel kettle. This was followed by three consecutive clean water rinses. Greens were water blanched for 1 min and steam blanched for 7 min in an autoclave to simulate a commercial hot water-steam blancher. Greens were drained, chopped with a Hobart cutter, and deposited in prelabeled freezer bags.

Table 1. Foliage disease severity and yield of leafy greens in turnip, spring 1988

Treatment[y]	Rate (kg a.i./ha)	Foliage discoloration and decay (%) 19 April	29 April	Yield (t/ha) Total	Acceptable for processing
Maneb + zinc	1.8	0.6	8 b[z]	46.1	19.6
Maneb + zinc	0.9	0.1	13 b	35.4	19.9
Benomyl	0.28	0.1	4 b	35.7	24.6
Chlorothalonil	1.26	0.1	5 b	42.5	33.8
Iprodione	0.17	0.3	11 b	34.5	20.3
Control	···	0.6	31 b	34.4	10.2

[y] Fungicides were applied 29 May and 6, 14, and 22 April.
[z] Numbers followed by the same letter are not significantly different according to the *t* test, $P = 0.05$.

After blast freezing (−29 C) and holding several days, approximately 900-g samples were cooked for 20–25 min by adding 473 ml of water per 454 g of product, according to manufacturer's recipe directions. During the process, 907-g samples were collected after the wash-rinse and cooking. This experiment was replicated four times. Samples of each lot and wash treatment collected before washing, after the wash-rinse, and after cooking were used for residue analysis.

Residue analysis. After 2–3 mo storage in a freezer, maneb was determined by the PAM II method (16). The lower limit of detection was 0.38 ppm. The amount of ETU in the spring crop was determined by modification of a method used by the Association of Official Analytical Chemists (3) with a lower limit of detection of 0.10 ppm. In the fall crop, the methods of Onley et al were used, and the lower limit of detection was 0.03 (15). The ETU tissue residues were determined by gas-liquid chromatography with a Tractor 565 gas chromatograph equipped with a Model 702 nitrogen/phosphorus detector. The column was 2 m × 4 mm packed with 10% Carbowax 20 M/2% KOH at 225 C, (spring crop) or a 60 m × 0.75 mm superflo SPB5 capillary at 160 C (fall crop). Inlet and detector temperatures were 250 C. Seven untreated samples of leafy greens were spiked with 1.0 ppm ETU, and 54–89% of the ETU was recovered (mean = 73%).

All yield and disease data were analyzed by least squares analysis statistical procedures (20). All percentage data were analyzed after an arcsine transformation, but means shown in the tables are the actual data before transformation. Data on chemical residues were not transformed before analysis. When no residue was detected in a sample, the minimum detectable level was used for statistical analysis. Residue data were analyzed by the *t* test because variances were not comparable. When some of the samples had nondetectable residues, the standard error reflects the substitution of the minimum detection level. When all samples were below the minimum detection level, no standard error was computed. For means that were compared, the variance was pooled and a new standard error was determined because all variances in a group were homogeneous, according to Cochran's test (20).

RESULTS

Disease control, spring crop. White spot (caused by *P. capsellae*) was first identified after 5 wk, and significant amounts of disease were observed 7 wk after planting (Table 1). All of the fungicide treatments reduced foliage disease severity 8 wk after planting (3 days before harvest).

Table 2. Foliage disease severity and yield of leafy greens in turnip, fall 1988

Treatment[u]	Rate (kg a.i./ha)	Leaf spots/plot (no.)[v]			Reflectance[w] (%)	Foliage discoloration and decay (%)[x]	Yield (t/ha)[y]	
		21 Sept.	26 Sept.	30 Sept.			Total	Acceptable for processing
Maneb + zinc	1.8	8	11 b[z]	124 bc	66.58 a	1.0 b	19.4	15.2 bc
Maneb + zinc	0.9	4	18 b	368 b	65.03 a	1.4 b	19.8	15.6 b
Benomyl	0.28	1	5 b	22 c	66.90 a	0.6 b	21.0	18.5 ab
Chlorothalonil	1.26	4	4 b	20 c	67.32 a	0.1 b	23.4	22.0 a
Iprodione	0.17	3	16 b	203 b	66.95 a	0.7 b	22.5	18.6 ab
Control	...	18	125 a	2,214 a	61.58 b	4.5 a	16.7	9.9 c

[u] Fungicides were applied 15, 22, and 30 September.
[v] White spot, induced by *Pseudocercosporella capsellae*.
[w] Measured 800 ± 13 nm on 6 October.
[x] Taken on 5 October.
[y] Harvested on 10 October.
[z] Numbers followed by the same letter are not significantly different according to the *t* test, $P = 0.05$.

Table 3. Product moment (Pearson) correlation coefficients of reflectance values[v], disease rating[w], percent discoloration and decay[x], and crop weight[y] of turnip, October 1988

Parameter	Reflectance (%)	Visual disease rating	Discoloration and decay (%)	Crop weight		
				Total	Unacceptable	Acceptable
Reflectance	...	−0.76	−0.74	0.54	−0.48	0.76
	...	0.0001[z]	0.0001	0.0056	0.0165	0.001
Visual disease rating	...	...	0.92	−0.13	0.67	−0.52
	...	...	0.0001	0.5547	0.0003	0.0097
Discoloration and decay	...	...	...	−0.15	0.80	−0.61
	...	...	...	0.4941	0.0001	0.0015
Crop weight						
Total	...	...	...	...	0.09	0.80
	...	...	...	...	0.6601	0.0001
Unacceptable	...	...	...	...	...	−0.53
	...	...	...	...	...	0.0083
Acceptable	...	...	...	...	...	...
	...	...	...	...	...	...

[v] Percent reflectance at 800 ± 13 nm on 6 October.
[w] Taken on 30 September.
[x] Taken on 5 October.
[y] Crop weights taken on 10 October.
[z] Level of probability.

Table 4. Foliage disease severity in the second cutting of leafy turnip greens, fall 1988

Treatment[x]	Rate (kg a.i./ha)	Foliage discoloration and decay[y] (%)	
		31 Oct.	14 Nov.
Maneb + zinc	1.8	6 b[z]	31 cd
Maneb + zinc	0.9	11 b	52 b
Benomyl	0.28	11 b	44 bc
Chlorothalonil	1.26	2 b	17 d
Iprodione	0.17	8 b	42 bc
Control	...	44 a	74 a

[x] Fungicides were applied on 13, 20, and 27 October.
[y] Primarily *Pseudocercosporella capsellae*, but *Alternaria* spp. was present at a low level (<1%) in the trial.
[z] Numbers followed by the same letter are not significantly different according to the *t* test, $P = 0.05$.

There were no differences in yield and percentage of leaves acceptable for processing among treatments. All plots were surrounded by unsprayed border beds of turnip, and disease severity at harvest in plots sprayed with fungicides was greater than would be expected if the entire field had been sprayed with fungicides.

Disease control, fall crop. White spot was detected in the field 3 wk after planting, and levels of white spot were severe by harvest. A few Cercospora leaf spots were identified 5 wk after planting, but they were observed rarely thereafter. All of the fungicide treatments gave significant control of white spot, and all treatments increased yield of leafy greens acceptable for processing, except maneb + zinc at 1.8 kg a.i./ha (Table 2). As in the spring test, unsprayed border rows and alleys were severely damaged by white spot.

Reflectance data indicated there were no significant differences among fungicide treatments and that all treatments were superior to the control plots (Table 2).

Data in Table 3 indicate a significant ($P \leq 0.0001$) negative correlation between percent reflectance and the visual disease rating ($r^2 = -0.76$), as well as the percentage of foliar discoloration and decay rating ($r^2 = -0.74$). Reflectance was the only parameter to show a significant correlation with total yield. All three parameters were correlated with unacceptable crop weights, but the percentage of discoloration and decay was the strongest ($r^2 = 0.80$). Although all three were also correlated with acceptable crop weights, reflectance was the strongest ($r^2 = 0.76$), indicating that multispectral radiometery may provide a quick, accurate method of assessing turnip yields.

Regrowth of leaves of the fall crop was free of leaf spot 1 wk after the first cutting. However, both Alternaria leaf spot and white spot were observed 31 October, and white spot was severe in early November. Alternaria leaf spots occurred in plots sprayed with benomyl and occasionally in other plots.

All of the fungicide treatments reduced foliage discoloration on 31 October and

Table 5. Residue levels ($\mu g/g$) of maneb and ethylenethiourea (ETU) in cooked and raw turnip greens grown with different fungicide treatments and processed with different washing methods, spring and fall 1988[x]

			Spring				Fall			
			Raw		Cooked		Raw		Cooked	
Fungicide	Rate (kg a.i./ha)	Washing method	Maneb	ETU	Maneb	ETU	Maneb	ETU	Maneb	ETU
Maneb + zinc	1.8	Alkaline detergent	1.37[y]	0.35	0.43	ND[z]	0.70	0.05	ND	0.04
		Detergent	1.25[y]	0.42	0.50	ND	1.02	ND	0.64	0.04
		Water	0.98	ND	0.44	ND	1.36	ND	ND	0.06
		Unwashed	1.35[y]	0.57	...	...	2.75	0.05	...	...
		Standard error	0.25	0.12	0.08	...	0.47	0.01	0.26	0.02
Maneb + zinc	0.9	Alkaline detergent	0.48	ND	ND	ND	1.38	ND	ND	0.05
		Detergent	0.81	ND	ND	ND	0.47	0.10	0.55	0.04
		Water	0.88	0.14	ND	ND	0.89	ND	0.54	ND
		Unwashed	0.88	0.17	...	...	1.92	0.08	...	...
		Standard error	0.36	0.06	...	...	0.38	0.06	0.17	0.02
Control	None	Alkaline detergent	ND	ND	ND	0.13	ND	ND	ND	ND
		Detergent	ND	ND	ND	ND	ND	ND	ND	ND
		Water	ND	0.20	ND	0.18	ND	ND	ND	ND
		Unwashed	0.51	0.35	...	...	ND	ND	...	...
		Standard error	0.13	0.16	...	0.04	...	...	...	...

[x]Average of four replications. There were no significant differences in residues among treatments within raw or cooked greens.
[y]Mean is significantly different from the minimum detectable level. Standard error was computed for each mean and pooled to provide a common standard error because the variances were homogeneous using Cochran's test (20).
[z]ND = no residues detected. When no residues were detected, minimum detection levels of 0.38 $\mu g/g$ of maneb or 0.10 $\mu g/g$ of ETU were used in computing the standard error.

Table 6. Effect of cooking on maneb and ethylenethiourea residue levels ± standard error ($\mu g/g$) in leafy greens, spring and fall 1988

			Spring		Fall	
Fungicide	Rate (kg a.i./ha)	Preparation	Maneb	ETU	Maneb	ETU
Maneb + zinc	1.8	Cooked	0.46	ND[z]	0.46	0.05
		Raw	1.22	0.39	0.99	0.04
		Standard error	0.11	0.06	0.14	0.01
Maneb + zinc	0.9	Cooked	ND	ND	0.49	0.04
		Raw	0.73	0.11	0.84	0.06
		Standard error	0.11	0.01	0.12	0.02
Control	...	Cooked	ND	0.14	ND	ND
		Raw	ND	0.11	ND	ND
		Standard error	...	0.03	...	...

[z]ND = no residues detected. When no residues were detected, minimum detection levels of 0.38 $\mu g/g$ of maneb or 0.10 $\mu g/g$ of ETU (0.03 in the fall) were used in the statistical analysis. Standard error was computed for each mean and pooled to provide a common standard error because the variances were homogenous using Cochran's test (20).

14 November compared with the control (Table 4). There were no differences in efficacy among fungicide treatments on 31 October, but sprays with chlorothalonil gave significantly better leaf spot control than any of the other fungicide treatments on 14 November. There was no significant difference in the efficacy of maneb at 1.8 kg a.i./ha compared with 0.9 kg a.i./ha on 31 October, but by 14 November, plots treated with 1.8 kg a.i./ha had significantly less leaf spot than plots treated with 0.9 kg a.i./ha (Table 3). All of the greens were considered nonsalable, and plots were not harvested.

Residue analysis, spring crop. The treatment means for maneb and ETU residues are given in Table 5. Methods of washing had no effect on residue levels in leafy greens. When only washed greens were included in the analysis, there were no significant differences in maneb or ETU residues among fungicide treatments, washing methods, or preparation methods (cooked vs. raw), but there was a significant fungicide treatment × preparation method interaction (Table 6). Both maneb and ETU residues were higher in raw than in cooked leafy greens from plots treated with 1.8 kg a.i./ha of maneb. In plots treated with 0.9 kg a.i./ha of maneb, residues of maneb were higher in raw than in cooked greens, but there were no significant differences between raw and cooked greens in levels of ETU. Maneb residues in leafy greens from control plots were below detectable levels, and ETU residues were detected in only three of 20 washed samples. The positive control samples possibly resulted from contamination of control plots by field equipment or spray drift. There were no significant differences in maneb and ETU residues between raw and cooked greens from control plots.

Residue analysis, fall crop. The treatment means for maneb and ETU residues are given in Table 5. All methods of washing the leaves reduced maneb residues significantly ($P = 0.05$) in raw greens sprayed with 1.8 kg a.i./ha. ETU residues were low, and there were no significant differences among treatments. In cooked greens, there were no differences in maneb or ETU residues among washing treatments. In unsprayed controls, no maneb or ETU residues were detected in raw or cooked greens.

Greater maneb residues were detected in raw greens than in cooked greens in both treatments sprayed with maneb + zinc F4, but there were no differences in ETU residues between raw and cooked greens (Table 6).

DISCUSSION

White spot is one of the most widespread foliage diseases of cruciferous leafy greens (5,22), and in our experiments, it was the most severe disease in both the spring and fall crops of turnip. All of the fungicides were effective in controlling *P. capsellae*, and maneb + zinc at one-half the currently labeled rate (0.9 kg a.i./ha) was as effective as the labeled rate (1.8 kg a.i./ha). Because other foliage diseases were observed infrequently, the efficacy of the reduced rate of maneb + zinc on other foliage diseases could not be determined. Chlorothalonil is not registered on leafy greens, and with the loss of maneb, there is no broad-spectrum foliage fungicide labeled currently on leafy greens.

The high correlation of the estimated percentage of foliage discoloration and decay and the percent reflectance of the 800-nm wavelength was similar to previous reports in other crops (2,14,19). The acceptability of greens for processing was more precisely estimated by reflectance than by visual estimates. In contrast, visual estimates were more closely related to the percentage of leaves unacceptable for processing than was reflectance. This is not surprising because reflectance is essentially a measure of the amount of healthy green leaf area present. To our knowledge, this is the first documented use of reflectance data to measure acceptability of leafy greens for processing, and it would appear to merit more research. Radiometry may be particularly well suited to such an application because the healthy leaf area is the commodity of value and not simply a variable influencing yield of grain, fruit, tubers, or pods (25).

In spinach, washing reduced levels of ETU (7–9). Washing with solutions of detergent or detergent plus chlorine with a high pH of 10.8–12.4 were the most effective methods of reducing ETU levels (0.1–3.1 ppm) in spinach sprayed with 1.8 kg a.i./ha of maneb 1 wk before harvest. Increasing the interval between the last spray and harvest reduced residues even more (7). However, disease control was inadequate in turnip if maneb was applied biweekly (21). For adequate disease control to meet industry standards, maneb + zinc needs to be applied until 10 days before harvest.

Washing reduced maneb but not ETU residues on the turnip greens in our research, but the methods of washing did not influence levels of residues significantly. However, if the pH of the washing solutions was increased from 9.7–9.9 to 11 or 12, washing might be as effective in turnip as it was in spinach (7–9). Cooking reduced levels of maneb consistently but had a variable effect on levels of ETU, compared with raw greens. Reducing the application rate of maneb + zinc was beneficial in reduced maneb residues but not ETU residues in greens. Turnip greens are rarely eaten without being washed and cooked, and ETU levels usually are undetectable (maximum 0.27 ppm in any sample) in washed, cooked greens in both crops of turnip regardless of the rate of maneb applied in the field.

ACKNOWLEDGMENTS

This research was supported by Southern Region Pesticide Impact Assessment Program, Southern Frozen Foods, and state funds allocated to the Georgia Agricultural Experiment Station and Cooperative Extension Service. No endorsements are implied herein. We thank Ben Mullinix, Agricultural Research statistician, for assistance in analyzing the data.

LITERATURE CITED

1. Aase, J. K., and Siddoway, F. H. 1980. Determining winter wheat stand densities using spectral reflectance measurements. Agron. J. 72:149-152.
2. Almihana, A. A. 1990. Comparison of green leaf area index, dry weight, disease intensity and percent reflectance measurements as inputs for modeling yield losses in peanuts. M.S. thesis. University of Georgia, Athens. 99 pp.
3. Association of Official Analytical Chemists. 1984. Official Methods of Analysis. 14th ed. Association of Official Analytical Chemists, Washington, DC. 1141 pp.
4. Chandler, W. A. 1965. Fungicidal control of anthracnose and white spot of turnip greens. Plant Dis. Rep. 49:419-422.
5. Crossan, D. F. 1954. Cercosporella leafspot of crucifers. N.C. Agric. Exp. Stn. Tech. Bull. 109. 23 pp.
6. Duggan, R., ed. 1990. Page 27 in: Pesticide Chemical Use Guide. Louis Rothschild, Jr., Washington, DC.
7. Gonzalez, A. R., Davis, D. R., Elkins, E. R., and Kim, E. S. 1989. Reduction of ethylenethiourea residues in canned spinach. HortScience 24:990-992.
8. Gonzalez, A. R., Davis, D. R., and Kattan, A. A. 1989. Effect of leaf type, leaf injury, storage temperature and washing solution on ethylenethiourea residues of carbamate-treated canned spinach. J. Food Saf. 9:155-164.
9. Gonzalez, A. R., Davis, D. R., Kattan, A. A., Elkins, E. R., and Kim, E. S. 1987. Effect of field and washing treatments on ethylenethiourea levels in ethylenebisdithiocarbamate-treated canned spinach. J. Food Saf. 8:225-233.
10. Graham, S. L., Davis, K. J., and Hansen, W. H. 1975. Effects of prolonged ethylenethiourea ingestion on the thyroid of the rat. Food Cosmet. Toxicol. 113:493-499.
11. Granberry, D. M. 1987. Survey of commercial vegetable acreage in Georgia. Ga. Coop. Ext. Serv. Univ. Ga. Leafl. 6 pp.
12. Marshall, W. D. 1977. Thermal decomposition of ethylenebisdithiocarbamate fungicides to ethylenethiourea in aqueous media. J. Agric. Food Chem. 25:357-361.
13. Newsome, W. H., and Laver, G. W. 1973. Effect of boiling on the formation of ethylenethiourea in zineb-treated foods. Bull. Environ. Contam. Toxicol. 10:151-154.
14. Nutter, F. W., Jr., Littrell, R. H., and Brenneman, T. B. 1990. Utilization of a multispectral radiometer to evaluate fungicide efficacy to control late leaf spot in peanut. Phytopathology 80:102-108.
15. Onley, J. H., Giuffrida, L., Ives, N. F., Watts, R. R., and Storherr, R. W. 1977. Gas-liquid chromatography and liquid chromatography of ethylenethiourea in fresh vegetable crops, fruits, milk, and cooked foods. J. Assoc. Off. Anal. Chem. 60:1105-1110.
16. Pease, H. L. 1957. Determination of dithiocarbamate fungicide residues. J. Assoc. Off. Agric. Chem. 40:1113-1118.
17. Ruddick, J. A., and Khera, K. S. 1975. Pattern of anomalies following single oral doses of ethylenethiourea to pregnant rats. Teratology 12:277-281.
18. Scheffer, R. P. 1950. Anthracnose leafspot of crucifers. N.C. Agric. Exp. Stn. Tech. Bull. 92. 26 pp.
19. Sharp, E. L., Perry, C. R., Scharen, A. L., Boatwright, G. O., Sands, D. C., Lautenschlager, L. F., Yahyaoui, C. M., and Ravet, F. W. 1985. Monitoring cereal rust development with a spectral radiometer. Phytopathology 75:936-939.
20. Steel, R. G. D., and Torrie, J. H. 1960. Principles and Procedures of Statistics. McGraw-Hill, New York. 481 pp.
21. Sumner, D. R. 1971. Effect of leafspots on quality of turnip greens grown for processing. Plant Dis. Rep. 55:540-543.
22. Sumner, D. R., Glaze, N. C., Dowler, C. C., and Johnson, A. W. 1978. Foliar diseases of turnip grown for greens in intensive cropping systems. Plant Dis. Rep. 62:51-55.
23. U.S. Department of Agriculture. 1953. United States standards for mustard greens and turnip greens. U.S. Consum. Mark. Serv. 3 pp.
24. U. S. Department of Agriculture. 1989. Agricultural statistics, 1989. U. S. Government Printing Office, Washington, DC. 547 pp.
25. Waggoner, P. E., and Berger, R. D. 1987. Defoliation, disease, and growth. Phytopathology 77:393-398.