Screening Onion Breeding Lines for Resistance to Onion Maggot (*Delia antiqua* Meigen) Damage

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Abstract

Investigations were carried out from 1995 to 1997 to screen onion breeding lines for resistance to onion maggot (OM) damage. Injury levels to direct-seeded and transplanted lines (altogether 35 entries) and 2 commercial cultivars at the seedling and mature bulb stage were evaluated in experimental plots in the Holland Marsh, southern Ontario, Canada. Differences in resistance expression were identified. The lines that tended to be most resistant to maggot damage were of the PS WR series. These were developed by PetoSeeds using germplasm from the onion breeding program at the University of Wisconsin, which focused on increasing resistance to *Allium* white rot. Expression of resistance was most evident at the seedling stage; in most cases differences in resistance were not as distinct at harvest. Levels of bulb damage were related to levels of seedling loss in onions grown from transplants but not in direct-seeded onions. Resistance studies on seeded and transplanted onions should be studied separately, since planting method can affect resistance ranking.

Introduction

The onion maggot (*Delia antiqua* Meigen, Diptera: Anthomyiidae) (OM) is a severe insect pest of onion (*Allium cepa* L.) crops grown in temperate regions of the northern hemisphere. This palearctic species was introduced into North America in the 19th century (Loosjes 1976). It dispersed throughout the continent, becoming one of the most important insect pests of onions grown in Canada (Harris et al. 1981; Ritcey and Chaput 2000). Although its host range extends to all *Allium* vegetables (Ellis and Eckenrode, 1979; McFerson et al. 1996) severe infestations, and resulting stand and yield losses, have been most often reported in onion crops (Baker 1927; Loosjes 1976; Harris et al. 1981; Brewster 1994). If not controlled, onion maggot infestations can prevent the production of marketable crops (Tolman et al. 1986).

In the climatic conditions of southern Ontario, onion yield on muck (organic) soils is higher and cost of production is lower than on mineral soils (Valk 1988). More than 60% of Ontario's onion crop (approximately 68,000 tonnes) is grown on the muck soils of the Bradford Holland Marsh (OMAFRA 1995). Spring sown bulbing onions are most common and comprise more than 1500 ha. Some early maturing cultivars are grown from seedlings started indoors and transplanted into the field as soon as weather and soil conditions permit (Valk 1988).

Onion production on muck soils is favourable for the development of OM (Perron 1972). In the Bradford area, newly emerged adults mate in mid-May. Gravid females deposit eggs in the soil around the base of onion seedlings. Females can deposit approximately 200 eggs during their life-time of about 30 days. Eggs hatch after several days and larvae start feeding on the subterranean part of the onion stem and, after bulb formation, on onion bulb tissue. Larvae mature in two to three weeks and leave the plant to pupate in soil (Ritcey and Chaput 2000).

Onions are most susceptible to OM damage when the first generation larvae are present (late May to beginning of July) and often, infested seedlings die before the maggots are fully grown. This damage results in stand loss and reduction in yield and quality. There is some compensation in yield, through increased growth of neighbouring onions, however, since damage tends to be clustered, empty sections of row and uneven growth in the remaining onions develop and reduce crop quality. During the second (mid-July) and third (late August and September) generations, the onion bulbs are larger and feeding by larvae does not kill plants; however, damaged bulbs are not marketable, so the proportion of damage is directly related to loss of marketable yield. Furthermore, damage caused by second and third generation maggots can predispose bulbs to rot as a result of secondary infections of fungi or bacteria (Loosjes 1976; Brewster 1994).

The most commonly used control measure is the application of insecticide to the soil to control first generation maggots. Later in the growing season, sprays may be applied to control adults (Harris et al. 1981; Liu et al. 1982). Intensive insecticide use has resulted in high mortality of natural enemies of the onion fly (Carruthers et al. 1985), and in the development of resistance in OM to several insecticides (Harris and Svec 1976; Carroll et al. 1983). Both insecticide resistance and environmental concerns limit utilization of chemical methods in OM control programs (Finch et al. 1986; Walters and Eckenrode 1996). Thus, there is a compelling demand for alternative control measures.

Plant resistance to insect damage is an attractive alternative or supplement to chemical control strategies. Resistance of various *Allium* species to OM infestation and damage has been studied by several workers (Harris et al. 1987; McFerson et al. 1996). Ellis and Eckenrode (1979) provided a general review of *Allium* and concluded that low levels of resistance may exist in bulb onions. The results of Ellis et al. (1979) and Eckenrode and Walters (1997) showed significant differences in resistance to OM damage among breeding lines evaluated throughout the time of first and second generation damage (late May through early July). We report here on the results of a three-year field study to screen seeded and transplanted onion lines for resistance to OM damage.

Materials and Methods

Plant material

Breeding lines, initially developed for disease resistance to *Allium* white rot (*Sclerotium cepivorum* Berk.), were obtained from Asgrow Seed Co., Ontario, Canada; Petoseed Co., California, U.S.A.; and the University of Wisconsin, Dept. of Horticulture (Dr. I. L. Goldman), Madison,WI, U.S.A. Seeds of the commercial cultivars, Norstar and Fortress, were provided by Stokes Seeds Ltd., Ontario, Canada and Asgrow Seed Co., Ontario, Canada, respectively.

Field evaluations

The study was carried out on muck soil at the Holland Marsh, Ontario (lat. 44° 15' N, long. 79° 60 ' W) under natural OM pressure. As seed stock allowed, 19, 24 and 18 direct seeded onion lines were evaluated in 1995, 1996 and 1997, respectively. In trials using transplanted onions, 20 lines (1996) and 17 lines (1997) were assessed. Seed for the lines missing from the transplant onion trials was received in time for direct seeding (May) but not early enough for starting in the greenhouse (March or April). Fortress and Norstar were used in both seeded and transplanted assays as commercial lines for comparison purposes.

The onion lines and selected commercial cultivars were direct seeded (V-Belt push seeder, Mechanical Welding Co. Ltd, Winnipeg, Man.) at approx. 40 seeds·m^{-1}, on 8, 16 and 21 May in 1995, 1996 and 1997, respectively. In all years, the initial stand was ascertained after seedling emergence, prior to OM adult emergence as determined by catches on yellow sticky traps. Transplants grown in a greenhouse were seeded on 10 April and 24 March in 1996 and 1997, respectively, and planted out by hand on 21-24 and 13-15 May, respectively.

Plots were set out in a randomized complete block design with 3 replicate blocks per line in 1995 and 4 replicate blocks per line in 1996 and 1997. Each direct seeded replicate consisted of 2 rows (42 cm apart), 3 m (1995) or 2 m (1996 and 1997) in length. Transplanted replicates consisted of two rows (approx. 42 cm apart), 4 m (1996) and 5 m (1997) in length. Transplants were planted at 10 cm spacing in both years. Crop management procedures followed standard cultivation practices (McDonald et al. 1997).

Field evaluations included only losses attributed to OM damage. Seedling loss from first generation maggots was recorded once a week. In all years, stand loss evaluations were initiated after the peak of onion fly catches on yellow sticky traps placed in other onion plots close to the resistance trial (28, 22, 24 June in 1995, 1996, 1997, respectively) and terminated in mid-July. Seedlings with symptoms of OM damage were removed to confirm the presence of maggots or characteristic damage at the base of the plant. For all treatments, final plant stand and onion bulb damage were recorded at harvest (for seeded onions: 29, 18, 30 September in 1995, 1996 1997, respectively and 27-29 August for transplanted onions in both 1996 and 1997).

Statistical analysis

The sum of counts from each evaluation week was divided by initial stand count to calculate percent of seedling damage due to first-generation maggot. Final percent onion damage was calculated by dividing the number of OM damaged (non-marketable) onions obtained at harvest by final stand count and multiplying by 100. The biennial nature of onion seed production did not permit the availablility of all lines each year. Therefore, statistical analyses were performed on within year data, except where damage levels between the same lines in two years were investigated by correlation analysis.

In order to compare groups of related lines from year to year, the mean damage for lines within a year were standardized. A selected mean was subtracted from the year mean, and the resulting term divided by the standard deviation for the year. A single average mean was then obtained from all the related means in a year for series starting with terms such as PS WR or XPH Means that are lower than the year mean result in a negative number, means higher that the year mean result in a positive number.

Percent data were arcsine transformed as described by Sokal and Rohlf (1995) and analyzed using Analysis of Variance (ANOVA). Comparisons among means were performed with Fishers Protected Least Significant Difference multiple range test, to allow for pair-wise comparisons between means (GLM, Post Hoc Multiple Comparisons, Bivariate Correlations, SPSS® for Windows ™, release 10.0, SPSS Inc., U.S.). Pearson Correlation analysis was used to examine the relationship between variables. (Statistix for Windows, Analytical Software, Tallahassee, FL). A type 1 error rate of a= 0.05 was set for all statistical tests.

Results

Evaluation of direct seeded lines in 1995, 1996, and 1997

Differences in OM damage to seedlings were found in each year (Tables I, II and III), however, the differences in bulb damage at harvest were significant (*P*= 0.002) only in 1995 (Table I), and

TABLE I. Onion maggot damage to seeded onion breeding lines and cultivars at the Holland Marsh, Ontario, 1995.

Line/Cultivar	Damaged seedlings (%)		Damaged bulbs at harvest[3] (%)	
PS WR 458	8.2	a[1]	21.1	e
W 457 b	10.5	a	15.0	de
W 454 b	13.2	ab	12.6	cd
Norstar	16.2	abc	4.8	ab
XPH 150 55	20.0	a-d	11.7	b-d
PS WR 459	20.1	a-d	6.6	abc
PSR 45 89 94	21.0	a-d	7.4	abc
W 458 b	21.3	a-e	10.4	a-d
XPH 150 58	22.7	a-f	14.5	de
PSR 45 96 94	23.4	a-g	13.2	cd
PSR 45 92 94	23.5	a-g	9.4	a-d
Fortress	25.0	a-g	3.8	a
XPH 150 59	28.2	b-h	13.0	cd
W 459 b	29.5	b-h	4.3	a
PSR 45 90 94	32.0	c-h	4.1	a
PSR 45 93 94	36.8	d-h	8.4	a-d
PSR 45 91 94	38.1	e-h	9.4	a-d
PSR 45 94 94	38.6	fgh	4.8	ab
XPH 150 56	40.1	gh	8.4	a-d
XPH 150 57	42.7	h	6.9	abc
PSR 45 95 94	43.6	h	8.4	a-d
Overall Mean Damage [2]	26.6	b	9.4	a
Standard deviation	10.2		4.4	

[1] Means in columns (non transformed data) followed by the same letter are not significantly different (a=0.05); Fishers Protected LSD).

[2] Means in the row followed by the same letter are not significantly different (Total df = 123, F for growth stage = 143.91, $P<0.0001$) .

[3] Pearson correlation coefficient between first generation OM damage to seedlings and bulbs at harvest : r= -0. 47 ($P<0.0001$).

TABLE II. Onion maggot damage to seeded and transplanted onion breeding lines and cultivars at the Holland Marsh, Ontario, 1996.

Line/Cultivar	Damaged seedlings(%)				Damaged bulbs at harvest [4] (%)			
	direct seeded		transplanted		direct seeded		transplanted	
PSR 45 93 94	0.2	a[1]	9.0	a-d	2.4	NS[2]	8.4	NS[2]
PS WR 458	1.0	a	4.0	ab	6.4		5.7	
(W) (429a x 454x455b)	1.3	a	7.8	a-d	5.5		10.1	
Fortress	1.5	a	7.8	a-d	3.6		11.6	
PSR 45 89 94	1.8	a	3.9	a-d	2.8		8.1	
W 454 b	2.0	a	6.4	a-d	6.5		3.5	
PSR 45 90 94	2.2	ab	4.2	a-d	4.0		2.7	
W 458 c	2.3	ab	2.8	abc	4.1		4.3	
W 459 c	2.6	abc	10.9	c-e	3.8		9.3	
W 457 c	2.7	abc	5.9	a-d	4.4		10.0	
(W) (440a x 458)x459c	3.1	abc	2.4	ab	5.1		4.9	
PSR 45 94 94	3.2	abc	2.9	ab	3.1		5.8	
PSR 45 96 94	3.3	abc	11.2	de	3.9		7.2	
PS WR 459	3.4	a-d	2.3	ab	5.3		4.5	
PSR 45 91 94	3.5	a-d	8.3	a-d	2.5		12.6	
PSR 45 95 94	3.6	a-d	10.5	b-e	4.9		12.2	
W 456 c	4.0	a-d	23.3	f	1.8		—-	
PSR 45 92 94	5.2	a-e	6.1	a-d	2.1		12.1	
XPH 150 55	6.1	b-e	—-		4.5		—-	
Norstar	6.6	b-e	1.0	a	5.1		6.3	
(W) (434a x 457)x458c	6.8	b-e	2.9	abc	4.4		2.3	
XPH 150 59	9.1	b-e	—-		5.8		—-	
XPH 150 57	9.4	cde	—-		3.9		—-	
XPH 150 58	10.3	de	—-		5.6		—-	
(W) (434a x 455)x456c	11.1	e	18.1	ef	5.7		14.5	
XPH 150 56	12.1	e	—-		4.5		—-	
W 455 b	—-		3.2	a-d	—-		—-	
Overall Mean Damage[3]	4.4	a	7.1	b	4.3	a	7.8	b
Standard deviation	4.9		8.0		3.0		7.7	

[1] Means in columns (non transformed data) followed by the same letter are not significantly different (a=0.05); Fishers Protected LSD, ANOVA of each variable separately.

[2] NS not significant (a =0.05)

[3] Means in the row followed by the same letter are not significantly different (a = 0.05), ANOVA of all variables (374 total df, *F*-test for planting method = 42.59, *P* =<0.0001.

[4] Pearson correlation coefficient between first generation OM damage to seedlings and bulbs at harvest for transplanted onions r = 0.75 (*P*<0.0001).

TABLE III. Onion maggot damage to seeded and transplanted onion breeding lines and cultivars at the Holland Marsh, Ontario, 1997.

Line/Cultivar	Damaged seedlings(%)				Damaged bulbs at harvest [4] (%)			
	direct seeded		transplanted		direct seeded		transplanted	
PS WR 456	5.4	a[1]	5.3	ab	27.8	NS[2]	15.2	a
W 459 c	9.4	ab	5.3	ab	20.2		18.4	a
W 456 c	9.7	ab	12.6	abc	30.8		33.5	ab
Fortress	13.0	abc	5.8	ab	39.4		14.9	ab
XPH 150 55	13.8	a-d	—-		27.5		—-	
PS WR 457	14.1	a-d	1.7	a	27.1		9.7	a
W 461 b	14.1	a-d	5.8	ab	31.4		16.0	ab
PS 650 00 96	14.3	a-d	2.1	a	24.6		9.2	a
W 458 c	15.4	a-d	12.4	abc	39.1		31.7	ab
W 454 b	15.4	a-d	21.2	c	53.9		57.5	b
W 457 c	16.8	a-e	14.2	bc	30.8		34.1	ab
W 455 b	17.6	a-e	21.8	c	48.6		54.3	b
PS 650 02 96	20.3	b-f	8.6	ab	32.0		22.9	a
(W) (434a x 457) x 458c	22.1	b-f	7.3	ab	34.6		18.0	a
Norstar	26.0	c-g	8.8	ab	29.6		18.4	a
(W) (440a x 458) x 459c	26.3	d-g	8.3	ab	29.3		17.3	a
(W) (429a x 454) x455b	29.3	efg	10.9	abc	26.9		30.3	ab
PS 650 01 96	33.2	fg	4.2	ab	33.8		15.6	a
(W) (434a x 455) x 456c	34.5	gh	8.9	ab	28.4		20.2	a
PS 650 03 96	46.6	h	2.9	ab	36.1		10.1	a
Overall Mean Damage [3]	19.9	ab	8.8	a	32.7	c	23.5	ab
Standard deviation	9.3		8.2		16.0		21.2	

1 Means in columns (non transformed data) followed by the same letter are not significantly different (a=0.05); Fisher's protected LSD)

2 NS - not significant (a = 0.05)

3 Means in the row followed by the same letter are not significantly different (a = 0.05), ANOVA of all variables (total df = 303, *F*-test for planting method 37.39, *P*<0.0001).

4 Pearson correlation coefficient between first generation OM damage to seedlings and to bulbs at harvest in transplanted entries : r = 0.95 (*P*<0.0001).

for onions grown from transplants in 1997 (*P* = 0.049, Table III). Average levels of seedling damage in 1995 and 1997 were similar while damage was considerably lower in 1996. The average levels of damage to mature bulbs also varied from year to year (Tables I, II and III).

In 1995, the lines with the least seedling loss were PS WR 458 and W457b (Table I). Highest seedling losses were observed in lines XPH 150 57 and PSR 45 95 94. Most lines exhibited seedling losses of between 13.2 % and 40.1 % with few significant differences. Bulb damage as a result of OM feeding also differed among the lines (*P*=0.001).

In 1996, the lines with the least seedling loss were PSR 45 93 94, PS WR 458, (W)(429ax454x455b), Fortress, PSR 45 89 94 and W 454b (Table II). Highest seedling losses were observed in lines XPH 150 58, (W)(434ax455)x456c and XPH 150 56. Most lines exhibited seedling damage of between 2.2 % and 9.4 % but the differences among most of these lines were not significant. There were no differences in OM damage to bulbs.

In 1997, the line with the lowest seedling loss was PS WR 456 (Table III). Highest seedling loss was observed in line PS 650 03 96. Most lines exhibited seedling losses of between 9.4 % and 33.2 % but differences among most of these lines were not significant. OM damage to bulbs was not different among lines, but damage in 1997 was 33.2% compared to only 4.3% in 1996.

First generation OM damage was not related to damage at harvest across most lines (Tables II, III), except in 1995 when seedling losses were negatively correlated with bulb damage ($r = -0.47$, $P < 0.0001$, Pearson correlation, Table 1). In 1995, maggot damage to bulbs was lower in most lines when compared with first generation OM damage to seedlings. However, lines PS WR 458 and W 457 b, which exhibited the lowest seedling loss, had the highest bulb damage (Table I). In the following years, low OM seedling damage in PS WR 458 (1996) and PS WR 456 (1997) was followed by high and mid-range levels of OM damage at harvest, respectively (Tables II, III).

In all years, OM damage levels in both commercial cultivars did not significantly differ from most breeding lines. Fortress and Norstar exhibited intermediate levels of seedling loss and bulb damage at harvest (Tables I, II and III).

Seed of all lines was not available each year. Pearson correlation of the lines that were the same showed no correlation between mean seedling loss as a result of OM damage of the 16 lines that were the same in 1995 and 1996 ($r = 0.07$, $P = 0.78$), the 12 lines that were the same in 1996 and 1997 ($r = 0.29$, $P = 0.35$) or the 7 lines that were the same in 1995 and 1997 ($r = -0.59$, $P = 0.16$). No relationships were identified in bulb damage between any of the trials over the three years.

Evaluation of transplanted lines in 1996 and 1997

Differences among transplanted lines and cultivars for OM damage to transplanted seedlings within years were significant ($P = 0.035$, 1996 and $P = 0.032$, 1997, Tables II and III); however, differences in bulb damage at harvest were significant only in 1997 ($P = 0.037$) (Table III). Average levels of OM damage to transplants were similar in 1996 and 1997. Average levels of damage to mature bulbs were different, 7.8 % in 1996 and 23.5 % in 1997 (Tables II and III).

In 1996, the line with the lowest transplant seedling loss was Norstar (Table II). Highest transplant seedling loss was found in the three lines, PSR 45 96 94, (W)(434ax455)x456c and W 456c, which had significantly higher damage than a group of six lines, including Norstar. Most of the lines exhibited levels of seedling damage of between 3.9 % and 10.9 %, but the differences were not significant. There were no differences in maggot damage to bulbs in 1996.

In 1997, the lines with the lowest transplant seedling losses were PS WR 457 and PS 650 00 96 (Table III). Highest transplant seedlings losses were observed in lines W 454 b and W 455 b. A group of 14 lines, including Norstar, had significantly less damage than these two lines. Most of the lines exhibited levels of seedling damage between 1.7% and 10.9% but the differences were not significant. Bulb damage as a result of onion maggot feeding differed significantly among lines ($P = 0.037$). The lowest levels of bulb damage in onions from transplants were found in lines PS 650 00 96 and PS WR 457, the same lines that had the lowest seedling loss. Bulb damage in these lines was significantly lower than in lines W 455b and W 454b, which had the highest damage.

OM damage levels to transplanted seedlings of both commercial cultivars did not differ significantly from most of the tested lines (Tables II, III). In 1996, Norstar had the lowest maggot damage, but the level was not significantly different from 16 other lines. Fortress had moderate damage. In 1997, maggot damage in Norstar and Fortress transplanted seedlings was intermediate, as was damage to bulbs at harvest, and did not differ significantly from any of the tested lines.

Evaluation of planting method and growth stage

Analysis of variance of arcsin transformed data of percent seedling and bulb damage in direct seeded and transplanted onion lines and cultivars within years revealed that levels of OM damage varied with planting method (P = 0.0001 in 1996 and P = <0.0001 in 1997), but the trends were opposite (Tables II and III). Levels of OM damage were lower on direct seeded onions in 1996, but higher in 1997.

Mean damage to direct- seeded seedlings and mature bulbs in 1995 and 1997 was significantly different (P < 0.0001 in both years) (Tables I and III). In 1995 seedlings had higher OM damage, but in 1997 OM damage was lower. There was no planting method (direct-seeded or transplanted) by growth stage (seedling or bulb) interaction in 1996 or 1997. No correlation between maggot damage in direct seeded and transplanted lines and cultivars was found for first generation damage. In 1997, bulb damage in seeded and transplanted onions was correlated (r = 0.71, P< 0.0001, Pearson's correlation). When untreated onions were grown from transplants, there was a positive correlation between first generation onion maggot damage and damage to bulbs, (r = 0.75, P < 0.0001 and r = 0.95, P < 0.0001, 1996 and 1997, respectively). This was not the case for direct seeded onions.

Comparisons of series of lines

Because of the year to year differences in damage levels, means of selected onion lines within groups or series were standardized to allow for comparisons from year to year. Lines in the PS WR series had the lowest OM damage in direct seeded onions in 1995 and 1997, and the second lowest in 1996. When the means of these PS WR lines in each trial were standardized, they were consistently negative (-1.22, -0.48 and –1.09, for direct seeded onions,1995, 1996 and 1997, respectively). Similar results were found in the onions grown from transplants (standardized means of -0.50 and –0.65, 1996 and 1997). The PS WR series was the only one where all of the standardized means were consistently negative, indicating that all were below the year mean for the seeding method. In contrast, standardized means of lines in the XPH150 series were positive (higher than the year mean) in 1995 (1.45) and 1996 (1.16) but the single line tested in 1997 was below the year mean (-0.65). Means of lines in the W series (W454 to W459) were lower than the year mean for most of the direct seeded trials (-0.79, -0.37 and -0.63 in 1995, 1996 and 1997, respectively) but levels of OM damage were greater than the year mean for onions grown from transplants (0.21 and 0.70 in 1996 and 1997).

Discussion

These field experiments confirmed that different levels of resistance to onion maggot damage could be identified in *A. cepa*. The varying levels of damage from year to year in these trials have also been reported in other studies on OM and *Allium* relationships (Ellis and Eckenrode 1979; McFerson et al. 1996; Eckenrode and Walters 1997). Screening of 37 entries over a 3-year period revealed that onion breeding lines were generally susceptible to OM attack and in most cases damage levels did not significantly differ from those found in commercial cultivars. Some entries exhibited moderate resistance to maggot damage when compared with other lines and cultivars, but none consistently resisted damage at a level that would be acceptable for commercial onion production.

As significant differences among levels of OM damage were found, some degree of resistance to OM damage may exist in certain lines. For example, lines from the PS WR series consistently showed the lowest OM damage at the seedling stage although the response was not as consistent at the harvest stage. Plant breeders could focus on the onion lines in this series to continue to investigate and improve the level of onion maggot resistance in onions.

Differences in levels of OM damage to onions and other *Allium* species are generally attributed to preference displayed by the females for oviposition sites (Loosjes 1976). Stand density in onions is not supposed to affect numbers of eggs per onion (Perron 1972), but Eckenrode and Walters (1997) reported a significant correlation between stand density and OM damage, which led them to assess onions grown from transplants, in order to achieve uniform stand. If high stand density does play a role in attracting female onion flies, this could contribute to the differences seen in damage levels between seedling and bulb onions in 1995. Onion lines that had low levels of seedling damage, which usually kills small onions, would have a denser stand later in the season, which might be more attractive for oviposition. Our data demonstrated that percent seedling loss from OM damage is related to bulb damage in onions grown from transplants but not from direct-seeded onions. Stand density tends to be more uniform in onions grown from transplants.

McFerson et al. (1996) also reported differences between OM resistance levels at the seedling and mature plant stages. The results of their study showed that some *Allium* accessions sustaining minimal damage as seedlings were nonetheless heavily damaged as mature plants by later generations. According to Perron (1972) undamaged, fully developed onions are not attacked by onion maggots, but onions with heavy, flaccid growth are known to be very attractive for oviposition (Loosjes 1976) so the phenology of larger or mature onions could influence damage levels.

Significant differences were found in levels of OM damage levels between direct seeded and transplanted lines. Harris et al. (1987) proposed antixenotic growth stages in onion and suggested that onion plants in certain growth stages were less preferred as suitable oviposition sites for onion flies due to differences in stem basal diameter. The results of Ellis et al. (1979) and Harris et al. (1987) strongly suggest that plant size plays an important role in host selection by *D. antiqua* and resulting levels of damage. Thus, plant size during the peak oviposition period could influence relative results. In this study, the onions grown for transplants in 1997 were started in the greenhouse 17 days earlier than in 1996 and planted out one week earlier, while the peak of onion fly catches on the sticky traps was two days later in 1997 than in 1996. Thus, the onion plants would be larger in 1997 when the onions flies emerged and began oviposition.

The differences in resistance to onion maggot damage in *A. cepa* reported here suggest that a search for *A. cepa* resistance to OM damage should be continued; however, seeded and transplanted entries should be studied separately since planting method can affect resistance ranking.

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