‘DMR-NY401’: A New Downy Mildew-resistant Slicing Cucumber

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The Cornell University vegetable breeding program has developed cucumbers (*Cucumis sativus* L.) resistant to a spectrum of diseases, including powdery mildew (Cavatorta et al., 2012; Jahn et al., 2002) and viruses (Munger, 1993). The program has also released a number of cultivars with multiple disease resistances, like the ‘Marketmore’ series (Cavatorta et al., 2007). The most recent release from this breeding program was a green slicing cucumber inbred line, ‘DMR-NY264’, that is resistant to cucurbit downy mildew (Holdsworth et al., 2014). Herein, we report the development of a new cucumber cultivar, DMR-NY401, with downy mildew resistance similar to ‘DMR-NY264’, but characterized by earlier maturation and higher yields.

Development of these newest cultivars was initiated in response to the rapid rise of cucurbit downy mildew as one of the greatest worldwide contemporary disease threats to cucumber production. Cucurbit downy mildew is characterized by angular chlorotic foliar lesions that quickly turn necrotic, and

often lead to rapid plant death (Savory et al., 2011). Diagnosis is aided by the presence of purplish-black sporangia of the causal oomycete pathogen, *Pseudoperonospora cubensis* (Berk. and Curt.) Rostov., which are often visible on the abaxial leaf surface. In the United States, sporangia are widely disseminated from overwintering sites in southern Florida to the eastern United States via wind currents (Granke and Hausbeck, 2011; Lebeda and Cohen, 2011; Ojiambo and Holmes, 2011). In recent years, it has been proposed that inoculum could be originating from new sources, like greenhouses in colder locales (Holmes et al., 2015), and new evidence suggests that the pathogen can be seed transmitted through infected plants (Cohen et al., 2014).

Managing this disease on cucumber in the United States became a challenge after the appearance of a new strain of the pathogen in 2004 in the southern United States (Holmes et al., 2015). The pathogen overcame host plant resistance that had lasted for decades, causing devastating yield losses (Colucci et al., 2006; Holmes et al., 2006). The ability of the pathogen to evolve rapidly has also reduced the efficacy of many fungicides, and resistance to a range of fungicides has been reported (Adams and Quesada-Ocampo, 2014; Urban and Lebeda, 2006; Zhu et al., 2007). Achieving durable control with fungicides is challenged by the recent spread of a new mating type (A2) of the pathogen to four continents within 5 years of its initial appearance (Cohen et al., 2015).

In response to the lack of host plant resistance available in commercially suitable germplasm after 2004 (Call and Wehner, 2010), Cornell University developed and released ‘DMR-NY264’, which built on earlier downy mildew resistance breeding work in the ‘Marketmore’ and ‘Poinsett’ series (Holdsworth et al., 2014). Although the genetic basis of downy mildew resistance is unknown (Cohen et al., 2015), ‘DMR-NY264’ likely derives its resistance from the additive genetic effects of its moderately downy mildew-resistant (‘DMR’) parents (Holdsworth et al., 2014). Although ‘DMR-NY264’ exhibits exceptional cucurbit downy mildew resistance, it is late to produce fruit, making it most useful in regions where growers are planting in anticipation of severe downy mildew pressure or have sufficient growing degree days to offset this lag. The

next step in the breeding process was developing an earlier and more prolific cucumber that retained the resistance of ‘DMR-NY264’ while continuing to improve on fruit type.

To develop this cucumber, ‘DMR-NY264’ was crossed to ‘Dasher II’, an early, green slicing cucumber (Fig. 1). Large F₂ populations of progeny from this cross were evaluated in the field under natural cucurbit downy mildew inoculum, harvested regularly, and the top-performing progeny were selected. Cuttings were taken from these selections, and were then intermated in the greenhouse. By opting to not pollinate in the field, many more plants at earlier generations could be observed without bias from fruit load. These intermated progeny were subsequently selfed, and the families were evaluated in, and selected from, the field. After that, selected progeny were selfed for two more generations to increase uniformity. From this process, an earlier and more prolific downy mildew-resistant line, ‘DMR-NY401’, was developed.

Description and Performance

‘DMR-NY401’ is a slicing cucumber, medium long in length (8–10”), with uniform green color and white spines (Fig. 2). The average marketable fruit weight was 0.2 ± 0.05 kg in conventional and 0.19 ± 0.02 kg

Fig. 1. Pedigree of Cornell downy mildew-resistant breeding line ‘DMR-NY401’. Between each field season, two generations were advanced in a winter greenhouse.

Fig. 2. Fruit of Cornell downy mildew-resistant inbred line, ‘DMR-NY401’.

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Table 1. AUDPC measurements for all trial entries under both organic and conventional management.

Trial entry ^{2y}	Organic trial AUDPC ^x	Conventional trial AUDPC ^x
DMR-NY264	306.8 a	528.3 a
DMR-NY401	473.5 ab	608.5 a
15-402	576.8 ab	550.8 a
15-407	708.2 abc	944.2 a
15-403	826.0 abc	687.0 a
15-404	879.7 bc	697.3 a
15-408	1,131.0 c	618.0 a
15-405	1,754.2 d	1,456.2 b
Marketmore 97	2,449.3 e	1,876.3 bc
SV4719CS (Seminis)	2,558.5 e	2,470.2 d
SV4220CS (Seminis) ^w	n.d.	2,622.3 de
Darlington (Seminis)	2,595.2 e	2,930.7 def
15-406	2,671.7 ef	1,928.8 c
Dasher II (Seminis)	3,144.3 fg	3,025.2 ef
Centella (Harris)	3,223.8 g	3,140.2 f
Straight Eight (Ferry-Morse)	4,196.8 h	3,678.7 g

²Data for all entries are reported as the mean of three replications.

^yTrial entry was highly significant in a one-way analysis of variance for both trials ($P < 0.0001$), and block was significant in the organic trial ($P = 0.0027$).

^zMeans in the same column followed by different letters are significantly different as determined by Tukey–Kramer honestly significant difference ($P < 0.05$) test.

^wSV4220CS^y was not evaluated in the organic trial.

Fig. 3. Images of plots from conventional trial on 8 Oct. 2015.

Table 2. AUDPC measurements for trial entries grown in 2014 under conventional management.

Trial entry ^{2y}	2014 AUDPC ^x
DMR-NY401 progenitor ^w	156.3 a
DMR-NY264	253.8 a
SV4719CS (Seminis)	730.8 b
Dasher II (Seminis)	835.3 bc
Straight Eight (Ferry-Morse)	991.8 c

²Data for all entries are reported as the mean of two replications.

^yTrial entry was highly significant in a one-way analysis of variance ($P < 0.0001$).

^zMeans in the same column followed by different letters are significantly different as determined by Tukey–Kramer honestly significant difference ($P < 0.05$) test.

^wDMR-NY401^y is a selection of the second selfed generation from the ‘DMR-NY401’ progenitor.

in organic trials. Importantly, ‘DMR-NY401’ retained the disease resistance of ‘DMR-NY264’ while increasing fruit length, yield, and earliness of initial harvest.

Disease resistance and yield were evaluated in conventional and organic trials for

‘DMR-NY401’ alongside Cornell University top early DMR breeding lines (15-402 to 15-408), commercial green slicing cultivars with advertised resistance to the post-2004 strain of the downy mildew pathogen (Table 1), and susceptible and resistant check cultivars, Straight Eight and DMR-NY264, respectively.

Seeds for the organic and conventional trials were sown on 16 July 2015 in Guterman Greenhouse (Ithaca, NY), and transplanted on 31 July 2015 at Freeville Organic Research Farm (Freeville, NY), and 3 Aug. 2015 at Homer C. Thompson Vegetable Research Farm (Freeville, NY), respectively, late in the season after the pathogen was reported in the region. Both trials were planted into rows covered in black plastic mulch, with 2.7-m spacing between rows, and arranged in a randomized complete block design with three replications of 10 plant plots. Plants were separated by 0.6 m within the plot, and by 1.8 m between plots. In addition, transplants for the conventional trial were treated with imidacloprid (Marathon[®], Bayer Environmental

Science, Research Triangle Park, NC) to control insect pests, and azoxystrobin (Heritage[®], Syngenta Crop Protection, Greensboro, NC) to control fungal diseases, such as powdery mildew, at labeled rates on 27 July 2015.

Downy mildew symptoms were first recorded in both trials on 14 Aug. 2015 (Table 1) and percent foliar disease was then recorded weekly. Other minor foliar diseases, including angular leaf spot (*Pseudomonas syringae* pv. *lachrymans*), alternaria leaf blight (*Alternaria cucumerina*), and powdery mildew (*Podosphaera xanthii*), were present in the organic trial, but their severity was extremely limited compared with downy mildew, and efforts were made to ensure symptoms due to these diseases were not recorded as percent foliar disease due to downy mildew. Other multistate trials in the eastern United States that included ‘DMR-NY401’ and its progenitors have also not reported significant disease due to downy mildew, and have observed field resistance to powdery mildew (M. Mazourek, unpublished data). Marketable fruits were harvested, counted, and weighed three times weekly beginning 4 Sept. 2015.

Trial data were assessed with a one-way analysis of variance, and the differences between individual trial entries were evaluated with the Tukey–Kramer honestly significant difference test in JMP Pro 11 (JMP[®], Version 11; SAS Institute Inc., Cary, NC, 1989–2007).

The downy mildew resistance of ‘DMR-NY401’, measured by area under the disease progress curve (AUDPC), was comparable to that of ‘DMR-NY264’ (Table 1), and these plants continued to grow up until frost (Fig. 3). This is consistent with AUDPC measured in breeding plots of the progenitor of ‘DMR-NY401’ compared with key representative commercial cultivars in the year prior (2014) that were grown under the conventional management regime previously described (Table 2). These data demonstrate consistency of the resistance of ‘DMR-NY401’ in separate downy mildew epidemics. In addition, both days to harvest and yield were improved in two very different open field production systems. The date of first harvest for ‘DMR-NY401’ was significantly shortened by ≈ 9 d compared with ‘DMR-NY264’ under both management regimes, and not statistically distinguishable from any of the commercial cultivars trialed (Table 3). In addition, ‘DMR-NY401’ had the highest fruit production of both trials—it outperformed commercial counterparts and ‘DMR-NY264’ (Table 3). Overall, ‘DMR-NY401’ has a timely harvest window and good yield while maintaining strong disease resistance.

Availability

Seed of ‘DMR-NY401’ is available by request to Michael Mazourek, Cornell University (mm284@cornell.edu).

Table 3. Date of first marketable fruit harvest and cumulative marketable fruit harvest and yield for all trial entries under both organic and conventional management.

Trial entry ^{2y}	Organic trial			Conventional trial		
	Fruit harvested per plot ^x	Fruit yield per plot (kg) ^x	Date of first harvest (days after sowing) ^x	Fruit harvested per plot ^x	Fruit yield per plot (kg) ^x	Date of first harvest (days after sowing) ^x
DMR-NY401	45.7 a	8.5 a	57 ab	47.7 a	9.6 a	57 ab
15-402	37 ab	6.8 ab	57 ab	30.7 abcd	6.2 abcd	55 ab
15-405	30.7 abc	5.5 abc	54 a	39 abc	6.3 abcd	57 ab
15-403	29.3 abc	5.5 abc	55 ab	43 ab	9 ab	58 ab
15-407	24 abcd	4.9 abcd	56 ab	23.7 bcd	4.7 bcde	61 bc
15-408	22.3 bcde	4.2 abcde	56 ab	34 abcd	7.5 abc	61 bc
DMR-NY264	17 bcde	3.1 bcde	65 c	13.7 de	2.6 de	66 c
SV4719CS (Seminis)	11.3 cde	2.9 bcde	53 a	29 abcd	3.9 cde	51 a
SV4220CS (Seminis) ^y	n.d.	n.d.	n.d.	28 abcd	3.8 cde	51 a
Marketmore 97	9.7 cde	1.9 cde	54 a	17 de	2.4 de	55 ab
15-404	9.3 cde	1.8 cde	62 bc	17 de	3.1 cde	61 bc
15-406	5 de	0.7 de	54 a	15 de	2.1 de	56 ab
Centella (Harris)	4.7 de	1 de	54 a	17.7 de	2.3 de	51 a
Dasher II (Seminis) ^w	4.3 de	0.7 de	55 ab	20.7 cde	2.5 de	51 a
Darlington (Seminis) ^w	3.3 de	0.4 e	61 abc	16 de	1.6 de	52 a
Straight Eight (Ferry-Morse)	0 e	0 e	N/A	0 e	0 e	N/A

²Data for all entries are reported as the mean of three replications.

^yTrial entry was highly significant in a one-way analysis of variance for both trials ($P < 0.0001$) for all reported results (number of fruit harvested per plot, fruit yield per plot, and date of first harvest), and block was significant in the organic trial for both cumulative fruit harvest ($P = 0.0021$) and yield ($P = 0.0021$).

^zMeans in the same column followed by different letters are significantly different as determined by Tukey–Kramer honestly significant difference ($P < 0.05$) test.

^wAverages of “Date of first harvest” for entry is the mean of two plots rather than three because one plot produced no marketable fruit before plant death.

^v“SV4220CS” was not evaluated in the organic trial.

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