

Supplementary Materials

Table S1 Further explanation of location, onion cultivation, and disease assessment in the disease survey fields

Year ^a	Location	Field	Investigation spot	Onion cultivation	Disease assessment of onion downy mildew	
				Mulching	Onion trial plots	Number of Assessed plants
2016	Saga	A	33°13'04.92"N, 130°18'43.46"E	Polythene mulch	1 × 1 m, 2 replicates	20 × 2
	Shiro-ishi	B	33°09'07.08"N, 130°09'16.87"E	—	1 × 1.5 m, 2 replicates	20 × 2
	Saga	C	33°13'04.82"N, 130°18'43.99"E	Polythene mulch	1 × 1 m, 2 replicates	20 × 2
	Shiro-ishi	D	33°11'55.95"N, 130°06'34.52"E	—	7.5 × 10 m, no replicates ^b	100 × 3
	Saga	E	33°13'04.93"N, 130°18'40.00"E	—	1 × 1 m, 2 replicates ^c	20 × 2
2017	Saga	F	33°13'04.04"N, 130°18'32.55"E	Polythene mulch	1 × 2 m, 3 replicates	50 × 3
	Shiro-ishi	B	33°09'07.08"N, 130°09'16.87"E	—	1 × 20 m, no replicates ^b	50 × 3
	Saga	E	33°13'03.34"N, 130°18'39.99"E	—	1 × 2 m, 2 replicates ^c	40 × 2
	Shiro-ishi	G	33°09'07.72"N, 130°09'14.90"E	—	1 × 2 m, 2 replicates ^c	20 × 2
2018	Saga	H	33°13'05.17"N, 130°18'42.48"E	Polythene mulch	1 × 2 m, 3 replicates	50 × 3
	Saga	I	33°13'12.99"N, 130°18'38.60"E	—	1 × 14 m, no replicates ^b	50 × 3
	Shiro-ishi	B	33°09'07.08"N, 130°09'16.87"E	—	1 × 20 m, no replicates ^b	50 × 3
	Shiro-ishi	G	33°09'07.72"N, 130°09'14.90"E	—	1 × 8 m, no replicates ^b	50 × 3

^a The year when the disease development was assessed

^b The area was divided into 3 quadrants, and 50–100 plants were randomly assessed within each section

^c Part of experiments from another study

Table S2 Meteorological stations located in the northern Kyushu district where the data used in this study were obtained

Meteorological stations ^a			Mounting height of observation equipment above the ground level (m)	
Location		Altitudes above sea level (m)	Electrical thermometer and electrical hygrometer	Combined wind vane and propeller anemometer
Saga City	33°15.9'N, 130°18.3'E	6	1.5	56.1
Sasebo City	33°9.5'N, 129°43.6'E	4	1.5	35.0
Fukuoka City 1	33°34.9'N, 130°22.5'E	3	1.5	—
Fukuoka City 2	33°34.9'N, 130°22.6'E	3	—	34.6
Kumamoto City 1	32°48.8'N, 130°42.4'E	38	1.5	—
Kumamoto City 2	32°49.3'N, 130°42.9'E	15	—	15.3

^a All meteorological stations mentioned are run by the Japan Meteorological Agency

Table S3 Decision logic regarding whether the disease development of onion downy mildew has occurred, the date obtained by back-calculating the latent period from the putative date of disease development, and the number of days of occurrence of favourable meteorological conditions for infection output by the risk model during the 3-day putative infection period^a

		Disease development occurrence (whether incidence or severity have increased by ≥10% per 5 days)							Putative date of disease development			Number of favourable meteorological condition days	
Year	Field	Starting point of each investigation			Next investigation			Decision: 0, no; 1, yes	Disease development (Date C: the middle day of Date A and B)	Latent days	Date D (Date back-calculated from Date C)	Infection period (the previous 3 days including Date D)	Favourable and marginal conditions output by the risk model
		Date A	Incidence (%)	Severity (%)	Date B	Incidence (%)	Severity (%)						
2016	A	19 Mar.	5.0	1.0	26 Mar.	10.0	2.0	0	22 Mar.	17	5 Mar.	3– 5 Mar.	0.50
		26 Mar.	10.0	2.0	31 Mar.	100	49.5	1	28 Mar.	21	7 Mar.	5– 7 Mar.	1.00
		31 Mar.	100	49.5	7 Apr.	100	67.5	1	3 Apr.	16	18 Mar.	16–18 Mar.	0
2016	B	25 Mar.	100	34.5	1 Apr.	100	48.0	0	28 Mar.	21	7 Mar.	5– 7 Mar.	1.00
2016	C	16 Apr.	100	25.5	23 Apr.	100	55.0	1	19 Apr.	10	9 Apr.	7– 9 Apr.	2.25
		23 Apr.	100	55.0	29 Apr.	100	87.0	1	26 Apr.	10	16 Apr.	14–16 Apr.	0.50
2016	D	30 Mar.	1.7	0.3	5 Apr.	2.3	0.5	0	2 Apr.	17	16 Mar.	14–16 Mar.	0
		5 Apr.	2.3	0.5	12 Apr.	8.0	1.6	0	8 Apr.	13	26 Mar.	24–26 Mar.	0
		20 Apr.	98.3	30.0	25 Apr.	100	42.1	1	22 Apr.	10	12 Apr.	10–12 Apr.	0.50
2016	E	19 Apr.	2.5	0.5	23 Apr.	37.5	7.5	1	21 Apr.	10	11 Apr.	9–11 Apr.	0.75
		2 May	50.0	11.5	9 May	92.5	21.0	1	5 May	10	25 Apr.	23–25 Apr.	2.75
		9 May	92.5	21.0	15 May	100	59.0	1	12 May	10	2 May	30 Apr.– 2 May	0.25
2017	F	28 Mar.	0	0	31 Mar.	0	0	0	29 Mar.	26	3 Mar.	1– 3 Mar.	0.25
		31 Mar.	0	0	4 Apr.	0	0	0	2 Apr.	23	10 Mar.	8–10 Mar.	0
		4 Apr.	0	0	7 Apr.	0	0	0	5 Apr.	21	15 Mar.	13–15 Mar.	0
		7 Apr.	0	0	11 Apr.	0	0	0	9 Apr.	16	24 Mar.	22–24 Mar.	0
		11 Apr.	0	0	14 Apr.	0	0	0	12 Apr.	13	30 Mar.	28–30 Mar.	0.25
		14 Apr.	0	0	17 Apr.	0	0	0	15 Apr.	11	4 Apr.	2– 4 Apr.	0.25
		17 Apr.	0	0	19 Apr.	22.0	4.4	1	18 Apr.	11	7 Apr.	5– 7 Apr.	1.00
		19 Apr.	22.0	4.4	23 Apr.	43.3	10.0	1	21 Apr.	11	10 Apr.	8–10 Apr.	3.00
		23 Apr.	43.3	10.0	25 Apr.	76.0	17.1	1	24 Apr.	10	14 Apr.	12–14 Apr.	0
		25 Apr.	76.0	17.1	28 Apr.	80.7	19.5	0	26 Apr.	10	16 Apr.	14–16 Apr.	1.00
2017	B	4 Apr.	0	0	7 Apr.	0	0	0	5 Apr.	21	15 Mar.	13–15 Mar.	0
		7 Apr.	0	0	11 Apr.	0	0	0	9 Apr.	16	24 Mar.	22–24 Mar.	0
		11 Apr.	0	0	14 Apr.	0	0	0	12 Apr.	13	30 Mar.	28–30 Mar.	0.25

Table S3 (continued)

Year	Field	Disease development occurrence (whether incidence or severity have increased by $\geq 10\%$ per 5 days)							Putative date of disease development			Number of favourable meteorological condition days	
		<i>Starting point of each investigation</i>			<i>Next investigation</i>			<i>Decision:</i> 0, no; 1, yes	<i>Disease development</i> (Date C: the middle day of Date A and B)	<i>Latent days</i>	<i>Date D</i> (Date back-calculated from Date C)	<i>Infection period</i> (the previous 3 days including Date D)	<i>Favourable and marginal conditions output by the risk model</i>
		Date A	Incidence (%)	Severity (%)	Date B	Incidence (%)	Severity (%)						
2017	B	14 Apr.	0	0	18 Apr.	0	0	0	16 Apr.	11	5 Apr.	3– 5 Apr.	0
		18 Apr.	0	0	21 Apr.	0	0	0	19 Apr.	11	8 Apr.	6– 8 Apr.	2.00
		21 Apr.	0	0	25 Apr.	81.3	18.1	1	23 Apr.	11	12 Apr.	10–12 Apr.	2.00
		25 Apr.	81.3	18.1	28 Apr.	92.7	23.1	1	26 Apr.	10	16 Apr.	14–16 Apr.	1.00
2017	E	10 Apr.	0	0	17 Apr.	0	0	0	13 Apr.	13	31 Mar.	29–31 Mar.	1.00
		17 Apr.	0	0	21 Apr.	0	0	0	19 Apr.	11	8 Apr.	6– 8 Apr.	2.00
		21 Apr.	0	0	24 Apr.	61.3	12.5	1	22 Apr.	11	11 Apr.	9–11 Apr.	3.00
		24 Apr.	61.3	12.5	27 Apr.	86.3	18.0	1	25 Apr.	10	15 Apr.	13–15 Apr.	0
		27 Apr.	86.3	18.0	2 May	95.0	20.5	0	29 Apr.	10	19 Apr.	17–19 Apr.	1.25
		2 May	95.0	20.5	6 May	100	25.0	0	4 May	10	24 Apr.	22–24 Apr.	0
		6 May	100	25.0	11 May	100	42.3	1	8 May	10	28 Apr.	26–28 Apr.	1.00
		11 May	100	42.3	15 May	100	64.8	1	13 May	10	3 May	1– 3 May	0.75
	G	7 Apr.	0	0	11 Apr.	0	0	0	9 Apr.	16	24 Mar.	22–24 Mar.	0
		11 Apr.	0	0	14 Apr.	0	0	0	12 Apr.	13	30 Mar.	28–30 Mar.	0.25
		14 Apr.	0	0	18 Apr.	0	0	0	16 Apr.	11	5 Apr.	3– 5 Apr.	0
		18 Apr.	0	0	21 Apr.	0	0	0	19 Apr.	11	8 Apr.	6– 8 Apr.	2.00
		21 Apr.	0	0	25 Apr.	0	0	0	23 Apr.	11	12 Apr.	10–12 Apr.	2.00
2018	H	25 Apr.	0	0	28 Apr.	2.5	0.5	0	26 Apr.	10	16 Apr.	14–16 Apr.	1.00
		23 Mar.	0	0	30 Mar.	0	0	0	26 Mar.	20	6 Mar.	4– 6 Mar.	1.50
		30 Mar.	0	0	2 Apr.	0.7	0.1	0	31 Mar.	16	15 Mar.	13–15 Mar.	2.00
		2 Apr.	0.7	0.1	5 Apr.	4.7	0.9	0	3 Apr.	14	20 Mar.	18–20 Mar.	2.00
		5 Apr.	4.7	0.9	10 Apr.	6.0	1.2	0	7 Apr.	11	27 Mar.	25–27 Mar.	1.00
		10 Apr.	6.0	1.2	13 Apr.	10.7	2.1	0	11 Apr.	11	31 Mar.	29–31 Mar.	0.25
		13 Apr.	10.7	2.1	18 Apr.	80.7	17.9	1	15 Apr.	11	4 Apr.	2– 4 Apr.	1.50
		18 Apr.	80.7	17.9	21 Apr.	93.3	24.3	1	19 Apr.	12	7 Apr.	5– 7 Apr.	1.50
		21 Apr.	93.3	24.3	26 Apr.	100	28.5	0	23 Apr.	10	13 Apr.	11–13 Apr.	0
	I	20 Mar.	0	0	27 Mar.	0	0	0	23 Mar.	19	4 Mar.	2– 4 Mar.	1.50

Table S3 (continued)

Year	Field	Disease development occurrence (whether incidence or severity have increased by $\geq 10\%$ per 5 days)							Putative date of disease development			Number of favourable meteorological condition days	
		Starting point of each investigation			Next investigation			Decision: 0, no; 1, yes	Disease development (Date C: the middle day of Date A and B)	Latent days	Date D (Date back-calculated from Date C)	Infection period (the previous 3 days including Date D)	Favourable and marginal conditions output by the risk model
		Date A	Incidence (%)	Severity (%)	Date B	Incidence (%)	Severity (%)						
2018	I	27 Mar.	0	0	30 Mar.	0	0	0	28 Mar.	18	10 Mar.	8–10 Mar.	1.00
		30 Mar.	0	0	2 Apr.	24.0	4.8	1	31 Mar.	16	15 Mar.	13–15 Mar.	2.00
		2 Apr.	24.0	4.8	5 Apr.	27.3	5.6	0	3 Apr.	14	20 Mar.	18–20 Mar.	2.00
		5 Apr.	27.3	5.6	10 Apr.	17.3	3.6	0	7 Apr.	11	27 Mar.	25–27 Mar.	1.00
		10 Apr.	17.3	3.6	13 Apr.	15.3	3.1	0	11 Apr.	11	31 Mar.	29–31 Mar.	0.25
		13 Apr.	15.3	3.1	16 Apr.	70.7	14.4	1	14 Apr.	11	3 Apr.	1– 3 Apr.	0.75
		16 Apr.	70.7	14.4	20 Apr.	96.7	22.4	1	18 Apr.	12	6 Apr.	4– 6 Apr.	2.25
		20 Apr.	96.7	22.4	23 Apr.	100	25.2	0	21 Apr.	10	11 Apr.	9–11 Apr.	0
		23 Apr.	100	25.2	27 Apr.	100	27.5	0	25 Apr.	11	14 Apr.	12–14 Apr.	0
2018	B	30 Mar.	0	0	3 Apr.	22.0	4.4	1	1 Apr.	16	16 Mar.	14–16 Mar.	1.25
		3 Apr.	22.0	4.4	9 Apr.	14.0	2.8	0	6 Apr.	10	27 Mar.	25–27 Mar.	1.00
		9 Apr.	14.0	2.8	13 Apr.	15.3	3.1	0	11 Apr.	11	31 Mar.	29–31 Mar.	0.25
		13 Apr.	15.3	3.1	16 Apr.	66.7	13.3	1	14 Apr.	11	3 Apr.	1– 3 Apr.	0.75
		16 Apr.	66.7	13.3	20 Apr.	100	32.9	1	18 Apr.	12	6 Apr.	4– 6 Apr.	2.25
		20 Apr.	100	32.9	23 Apr.	100	38.9	0	21 Apr.	10	11 Apr.	9–11 Apr.	0
		23 Apr.	100	38.9	27 Apr.	100	36.7	0	25 Apr.	11	14 Apr.	12–14 Apr.	0
2018	G	3 Apr.	1.3	0.3	9 Apr.	1.3	0.3	0	6 Apr.	10	27 Mar.	25–27 Mar.	1.00
		9 Apr.	1.3	0.3	13 Apr.	1.3	0.3	0	11 Apr.	11	31 Mar.	29–31 Mar.	0.25
		13 Apr.	1.3	0.3	16 Apr.	25.3	5.1	1	14 Apr.	11	3 Apr.	1– 3 Apr.	0.75
		16 Apr.	25.3	5.1	20 Apr.	42.7	8.5	1	18 Apr.	12	6 Apr.	4– 6 Apr.	2.25
		20 Apr.	42.7	8.5	23 Apr.	60.0	12.0	1	21 Apr.	10	11 Apr.	9–11 Apr.	0
		23 Apr.	60.0	12.0	27 Apr.	58.0	11.6	0	25 Apr.	11	14 Apr.	12–14 Apr.	0
		27 Apr.	58.0	11.6	1 May	100	38.5	1	29 Apr.	10	19 Apr.	17–19 Apr.	1.00
		1 May	100	38.5	7 May	100	52.5	1	4 May	10	24 Apr.	22–24 Apr.	2.00
		7 May	100	52.5	11 May	100	59.5	0	9 May	10	29 Apr.	27–29 Apr.	0.50
		11 May	100	59.5	14 May	100	75.2	1	12 May	10	2 May	30 Apr.– 2 May	1.00

^a See Fig.4 for the flow chart to evaluate the relationship between the meteorological conditions during putative infection period and the probability of disease development

Table S4 Latent periods of *P. destructor* under each temperature condition used in this study^a

	Temperature (°C)													
	4–5	6	7	8	9	10	11	12	13	14	15	16	17	18–25
Latent period (days)	60	51	45	35	30	25	22	18	15	13	12	11	11	10

^a We prepared this table based on the report of DEFRA (2002)

Table S5 Further explanation of list of the fungicides included in fungicide experiments 1–5^a

Fungicide active ingredients (% a.i.)	Trade name and formulation ^b	FRAC Code ^c	Dosage (%) ^d	Concentration of a.i. used ^e
Chlorothalonil 50% +Benthiavalicarb-isopropyl 5%	Propose WDG	M5 + 40	0.1	Ch: 500 mg/L Be: 50 mg/L
Chlorothalonil 32% +Metalaxyl-M 3.3%	Folio Gold SC	M5 + 4	0.125	Ch: 400 µL/L Me: 41.25 µL/L
Chlorothalonil 40%	Daconil 1000 SC	M5	0.1	400 µL/L
Mancozeb 80%	Zimandaisen WP	M3	0.25	2000 mg/L

^a The number of replicates and the area of each experimental plot are the same as those of the unsprayed plot in Table 1. The numbers of infected plants placed in each plot in fungicide experiments 1-1, 1-2, 3, 4, and 5 were 4, 4, 2, 4, and 3, respectively (same as those of the unsprayed plot in Table 1). The pot-grown primary infected plants were temporarily removed from the experimental field during fungicide application and then returned to their original position

^b WDG = water dispersible granule, SC = suspension concentrate, WP = wettable powder

^c FRAC codes from the Fungicide Resistance Action Committee (<http://www.frac.info/frac/>)

^d In Japan, fungicide solution is often sprayed at approximately 1000–2500 L/ha in onion fields. In this study, fungicide solution was sprayed at 1300 L/ha in experiment 2, 1500 L/ha in experiments 1-1, 1-2, and 3, and 2500 L/ha in experiments 4 and 5. Each fungicide applied in the field was dissolved in water based on the labelled rate

^e Ch = Chlorothalonil, Be = Benthiavalicarb-isopropyl, Me = Metalaxyl-M

Table S6 Temperature and precipitation during the period when the onion plants were cultivated in the main field^a

Crop season	Period	Temperature			Precipitation
		Mean maximum (°C)	Mean minimum (°C)	Mean (°C)	Total (mm)
Autumn 2015 –spring 2016	Nov. 2015	20.1	12.4	15.9	145.5
	Dec. 2015	13.7	5.7	9.5	104.0
	Jan. 2016	9.7	2.6	6.1	82.0
	Feb. 2016	12.0	2.8	7.1	75.5
	Mar. 2016	16.3	6.7	11.2	76.5
	Apr. 2016	22.2	12.4	17.1	246.5
	May 2016	27.0	16.1	21.3	275.5
Autumn 2016 –spring 2017	Nov. 2016	18.2	9.6	13.7	155.0
	Dec. 2016	14.0	5.4	9.4	78.0
	Jan. 2017	11.1	2.2	6.4	32.0
	Feb. 2017	12.3	2.4	7.0	85.5
	Mar. 2017	14.7	5.5	9.8	48.0
	Apr. 2017	21.7	11.9	16.4	222.0
	May 2017	26.8	15.9	20.9	111.0
Autumn 2017 –spring 2018	Nov. 2017	17.3	8.2	12.6	19.0
	Dec. 2017	10.4	1.9	6.1	17.0
	Jan. 2018	8.8	1.0	4.6	70.0
	Feb. 2018	10.2	1.3	5.4	49.0
	Mar. 2018	17.6	6.5	11.8	173.5
	Apr. 2018	22.6	11.7	17.1	169.5
	May 2018	25.6	16.4	20.8	170.5

^a We used data from the meteorological station at Saga (33°15.9'N, 130°18.3'E) in Kyushu, western Japan, monitored by the Japan Meteorological Agency