

1 **Downy mildew of buckwheat, *Fagopyrum esculentum*, in the USA caused by *Peronospora***  
2 ***cf. ducometii*.**

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6 Buckwheat (*Fagopyrum esculentum*, Polygonaceae) seed is milled into a flour to make soba  
7 noodles, and is used whole or milled in breads, pastries, soups, and porridges. Buckwheat was  
8 grown on ~5,000 ha in Washington State in 2016, and central Washington is an important region  
9 for buckwheat seed production. Symptoms of downy mildew were observed in buckwheat trials  
10 at the Washington State University (WSU) Mount Vernon Northwestern Washington Research  
11 and Extension Center (NWREC) in Skagit Co., WA in 2014, 2015, and 2016; and in growers'  
12 buckwheat crops in Jefferson Co. and Skagit Co., WA in 2016 at incidences of 33 to 100%. Pale  
13 green, 5- to 40-mm-diameter lesions on the adaxial leaf surface became chlorotic and,  
14 sometimes, necrotic. Under moist conditions, sparse, hyaline to light gray sporulation developed  
15 on the abaxial leaf surface. Conidiophores typical of *Peronospora* developed from stomata  
16 individually or, infrequently, in groups of two or three; were 408 to 824  $\mu\text{m}$  (mean  $\pm$  standard  
17 deviation of  $572 \pm 92 \mu\text{m}$ ,  $n = 50$ )  $\times$  5 to 11  $\mu\text{m}$  ( $9.1 \pm 1.2 \mu\text{m}$ ), and branched submonopodially 4  
18 to 7 (mostly 6) times with the ultimate branches right angled and each bearing a sporangium. At  
19 least one of each ultimate branch per pair ( $n = 50$ ) was curved slightly, with the longer branch  
20 4.5 to 12.0  $\mu\text{m}$  ( $7.2 \pm 1.8 \mu\text{m}$ ) and the shorter branch 3.0 to 7.5  $\mu\text{m}$  ( $5.0 \pm 1.1 \mu\text{m}$ ). Hyaline to  
21 light brown, lemon-shaped conidia ( $n = 50$ ) became oval at maturity, and were 16.5 to 35.5  $\mu\text{m}$   
22 ( $27.9 \pm 5.0 \mu\text{m}$ )  $\times$  14.0 to 20.0  $\mu\text{m}$  ( $16.7 \pm 1.7 \mu\text{m}$ ) with a 1.0 to 2.3 length:width ratio. A sample  
23 was submitted to the U.S. National Fungus Collections of the United States Department of

1 Agriculture (USDA) Systematic Mycology and Microbiology Laboratory (BPI910167). The  
2 internal transcribed spacer (ITS) 1-5.8s ribosomal RNA-ITS2 DNA sequence (GenBank  
3 Accession KX774332) was 100% homologous to that of *Peronospora* cf. *fagopyri* (KP271924)  
4 (Pertrželová et al. 2015), which should have been named *P. ducometii* as the disease was first  
5 reported in France by Ducomet (1910). The *cytochrome oxidase 2* (cox2) sequence (KX777249)  
6 was 99% homologous to that of *P. polygoni* KJ654235 (Choi et al. 2015), with no cox2  
7 sequences of *P. ducometii* or *P. fagopyri* in GenBank. A conidial suspension ( $1.4 \times 10^4$   
8 conidia/ml, prepared by washing infected leaves in 0.0125M phosphate buffer) was atomized  
9 onto twelve 14-day-old seedlings of buckwheat cvs. Koto and Springfield, and a breeding  
10 population of Nash Huber, after incubating seedlings overnight in plastic bags. Twelve control  
11 plants/cultivar were misted with buffer. Plants were then enclosed in plastic bags at 18°C for 24  
12 h in the dark, bags removed, and the plants held at 18/14°C by day/night with 16 h daylength.  
13 Downy mildew sporulation was observed on Koto after 8 days, and on the other two entries after  
14 19 days. Sporulation was not observed on control plants. Severity of downy mildew was rated in  
15 August 2016 for 120 Plant Introduction (PI) lines planted from a global buckwheat collection of  
16 the USDA National Plant Germplasm System. The 110 *F. esculentum* PIs averaged  $1.7 \pm 1.0$   
17 downy mildew severity (0-to-3 scale), with 14 asymptomatic (**eXtra**). The 10 *F. tataricum* PI  
18 lines averaged  $0.1 \pm 0.3$  downy mildew severity, with 9 asymptomatic. Buckwheat downy  
19 mildew has been reported in many countries (Farr and Rossman 2016; Pertrželová et al. 2015)  
20 but this is the first record of outbreaks of the disease in Washington State and the USA, with  
21 evidence of resistance in some *F. tataricum* and *F. esculentum* PIs that could be used in breeding  
22 programs.

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1 *References:*

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7 Pertrželová, I., et al. 2015. Plant Dis. 99:1178.

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9 78:113.

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1 **eXtra Table.** Severity of downy mildew observed on 120 cultivars or entries of buckwheat  
 2 (*Fagopyrum esculentum* and *F. tataricum*) obtained from the United States Department of  
 3 Agriculture (USDA) National Plant Germplasm System (NPGS) and planted at the Washington  
 4 State University (WSU) Mount Vernon Northwestern Washington Research and Extension  
 5 Center in 2016.<sup>a</sup>

Plant Intro- duction (PI) No.	Cultivar or other name	<i>Fagopyrum</i> species <sup>b</sup>	Geographic origin	Severity of downy mildew <sup>c</sup>
PI 263949	PA 127	<i>F. esculentum</i>	Serbia	2
PI 263950	PA 128	<i>F. esculentum</i>	Serbia	1
PI 280832	No. 3872	<i>F. esculentum</i>	Soviet Union	1
PI 280833	PA 147	<i>F. esculentum</i>	Russian Federation	1
PI 481641	330	<i>F. esculentum</i>	Bhutan	2
PI 481643	411	<i>F. esculentum</i>	Bhutan	2
PI 482595	TGR 873	<i>F. esculentum</i>	Zimbabwe	3
PI 482596	TGR 1375	<i>F. esculentum</i>	Zimbabwe	3
PI 482597	TGR 1491	<i>F. esculentum</i>	Zimbabwe	3
PI 647589	PA 010	<i>F. esculentum</i>	United States	3
PI 647594	Tokyo/PA 011	<i>F. esculentum</i>	Canada	2
NA	Breeding line, WSU	<i>F. esculentum</i>	United States	1
PI 647597	Takan/PA 149	<i>F. esculentum</i>	Taiwan	3
PI 647600	Iwatezairai/PA 083	<i>F. esculentum</i>	Japan	3
PI 647602	PA 144	<i>F. esculentum</i>	United States	3
PI 647615	Pennline 18	<i>F. esculentum</i>	United States	2
PI 647642	Aomori	<i>F. esculentum</i>	Japan	3
PI 647643	Gunma Prefectura	<i>F. esculentum</i>	Japan	2
PI 647659	Japanese B 0-61-10	<i>F. esculentum</i>	Canada	3
PI 647662	Kasho-2	<i>F. esculentum</i>	Japan	3
PI 647663	Southern Chinese	<i>F. esculentum</i>	Canada	3
PI 647666	Tohno Zairai	<i>F. esculentum</i>	Canada	3
PI 658413	Kasho	<i>F. esculentum</i>	United States	2
PI 658426	G 29301	<i>F. esculentum</i>	Nepal	3
PI 658428	Solianskaja	<i>F. esculentum</i>	Russian Federation	1
PI 658432	Mancan	<i>F. esculentum</i>	Canada	3
PI 658433	Manor	<i>F. esculentum</i>	Canada	3
PI 658434	Giant American	<i>F. esculentum</i>	United States	3
PI 658436	Martin's Alaska	<i>F. esculentum</i>	United States	3
PI 658441	PA 001	<i>F. esculentum</i>	United States	3

PI 658443	PA 017	<i>F. esculentum</i>	United States	2
PI 658445	PA 093	<i>F. esculentum</i>	Italy	2
PI 658446	CIfa 33	<i>F. esculentum</i>	Italy	3
PI 280831	No. 3790	<i>F. esculentum</i>	Soviet Union	1
PI 481628	1	<i>F. esculentum</i>	Bhutan	1
PI 481629	17	<i>F. esculentum</i>	Bhutan	1
PI 481630	23	<i>F. esculentum</i>	Bhutan	1
PI 481631	28	<i>F. esculentum</i>	Bhutan	0
PI 481632	35	<i>F. esculentum</i>	Bhutan	1
PI 481635	186	<i>F. esculentum</i>	Bhutan	1
PI 481637	274	<i>F. esculentum</i>	Bhutan	1
PI 481638	277	<i>F. esculentum</i>	Bhutan	2
PI 481639	299	<i>F. esculentum</i>	Bhutan	1
PI 481640	304	<i>F. esculentum</i>	Bhutan	1
PI 481642	373	<i>F. esculentum</i>	Bhutan	1
PI 590989	Chaselimadao	<i>F. esculentum</i>	China	1
PI 633688	Pennline 25	<i>F. esculentum</i>	United States	1
PI 633689	MC 056	<i>F. esculentum</i>	Soviet Union	1
PI 633690	MC 057	<i>F. esculentum</i>	India	2
PI 647588	PA 003	<i>F. esculentum</i>	United States	3
PI 647590	PA 013	<i>F. esculentum</i>	United States	3
PI 647591	PA 014	<i>F. esculentum</i>	United States	3
PI 647592	PA 015	<i>F. esculentum</i>	United States	3
PI 647593	PA 019	<i>F. esculentum</i>	United States	2
PI 647595	CIfa 12	<i>F. esculentum</i>	United States	3
PI 647598	Pulawska/PA 054	<i>F. esculentum</i>	Poland	2
PI 647599	PA 056	<i>F. esculentum</i> + several <i>F. tataricum</i>	Switzerland	2
PI 647618	Tempest	<i>F. esculentum</i>	Canada	2
PI 647619	MC 033	<i>F. esculentum</i>	Poland	1
PI 647620	MC 034	<i>F. esculentum</i>	Poland	1
PI 647621	MC 035	<i>F. esculentum</i>	Canada	1
PI 647622	MC 036	<i>F. esculentum</i>	Poland	0
PI 647623	MC 037	<i>F. esculentum</i>	Poland	1
PI 647624	MC 038	<i>F. esculentum</i>	Canada	0
PI 647625	MC 039	<i>F. esculentum</i>	Poland	0
PI 600909	Winsor Royal	<i>F. esculentum</i>	United States	2
PI 647626	MC 042	<i>F. esculentum</i>	Poland	0
PI 647627	MC 043	<i>F. esculentum</i>	Poland	0
PI 647628	MC 044	<i>F. esculentum</i>	Poland	0
PI 647629	MC 045	<i>F. esculentum</i>	Poland	0

PI 647630	MC 046	<i>F. esculentum</i>	Poland	1
PI 647631	MC 047	<i>F. esculentum</i>	Poland	1
PI 647632	MC 048	<i>F. esculentum</i>	Poland	0
PI 647633	MC 049	<i>F. esculentum</i>	Poland	0
PI 647634	MC 174	<i>F. esculentum</i>	United States	3
PI 647635	MC 258	<i>F. esculentum</i>	Poland	1
PI 647636	MC 052	<i>F. esculentum</i>	Soviet Union	0
PI 647637	MC 054	<i>F. esculentum</i>	Soviet Union	1
PI 647638	MC 060	<i>F. esculentum</i>	Soviet Union	2
PI 647639	CD 6183	<i>F. esculentum</i>	Canada	1
PI 647641	CD 8217	<i>F. esculentum</i>	Soviet Union	0
PI 647644	Kanada	<i>F. esculentum</i>	Japan	2
PI 647645	Japanese B 0 IR-13	<i>F. esculentum</i>	Japan	3
PI 647646	Japanese B 0 IR-5	<i>F. esculentum</i>	Canada	3
PI 647652	MC 259	<i>F. esculentum</i>	Poland	1
PI 647655	Chinese	<i>F. esculentum</i>	Canada	2
PI 647660	K-3401	<i>F. esculentum</i>	Soviet Union	1
PI 647661	K-3466	<i>F. esculentum</i>	Soviet Union	2
PI 647664	Sweden-1	<i>F. esculentum</i>	Sweden	0
PI 647665	Sweden-2	<i>F. esculentum</i>	Sweden	1
PI 647701	CM 221	<i>F. esculentum</i>	Canada	2
PI 658415	G 27890	<i>F. esculentum</i>	China	2
PI 658416	G 27891	<i>F. esculentum</i>	China	3
PI 658417	G 29291	<i>F. esculentum</i>	Nepal	3
PI 658427	Pulawska II	<i>F. esculentum</i>	Poland	1
PI 658435	Hruzgowska	<i>F. esculentum</i>	Poland	1
PI 658440	Enka	<i>F. esculentum</i>	Denmark	1
PI 658442	PA 018	<i>F. esculentum</i>	United States	3
PI 658447	PA 002	<i>F. esculentum</i>	United States	2
PI 658448	PA 012	<i>F. esculentum</i>	United States	2
PI 427235	No known identification	<i>F. esculentum</i> + <i>F.</i> <i>tataricum</i>	Nepal	1
PI 427236	No known identification	<i>F. esculentum</i>	Nepal	2
PI 451723	Trigo Saraceno O'Alforfon	<i>F. tataricum</i>	Mexico	1
PI 481634	171	<i>F. esculentum</i> + <i>F.</i> <i>tataricum</i>	Bhutan	2
PI 481636	211	<i>F. esculentum</i> + 2 <i>F.</i> <i>tataricum</i> plants	Bhutan	1
PI 590988	Yuqiao No. 2	<i>F. esculentum</i>	China	2
PI 647601	Nostrano	<i>F. esculentum</i>	Italy	2
PI 647614	CIfa 41	<i>F. tataricum</i>	United States	0

PI 647640	CD 7272	<i>F. esculentum</i>	Czechoslovakia	0
PI 653410	CIfa 40	<i>F. tataricum</i>	United States	0
PI 658414	G 27889	<i>F. esculentum</i>	China	2
PI 658418	G 29292	<i>F. tataricum</i>	Nepal	0
PI 658419	G 29294	<i>F. tataricum</i>	Nepal	0
PI 658420	G 29295	<i>F. tataricum</i>	Nepal	0
PI 658421	G 29296	<i>F. tataricum</i>	Nepal	0
PI 658422	G 29297	<i>F. tataricum</i>	Nepal	0
PI 658423	G 29298	<i>F. tataricum</i>	Nepal	0
PI 658424	G 29299	<i>F. tataricum</i>	Nepal	0
PI 658437	Sperli	<i>F. esculentum</i>	Switzerland	1
PI 658444	Laharpe/PA 029	<i>F. esculentum</i>	France	1
Mean ± standard deviation (minimum – maximum) of all 120 entries				1.5 ± 1.1 (0-3)
Mean ± standard deviation (minimum – maximum) of 110 <i>F. esculentum</i> entries (including those with mostly <i>F. esculentum</i> plant type) <sup>b</sup>				1.7 ± 1.0 (0-3)
Mean ± standard deviation (minimum – maximum) of 10 entries with <i>F. tataricum</i> plant type <sup>b</sup>				0.1 ± 0.3 (0-1)

1 <sup>a</sup> A single replicate plot of 25 seeds of each buckwheat entry was planted on 3 June 2016. Entries were not planted  
2 in replicate plots because of limited seed available from the USDA NPGS.

3 <sup>b</sup> All PIs planted in this trial were listed by the USDA NPGS as *F. esculentum* but the morphology of a subset or all  
4 plants in some plots was typical of *F. tataricum* (USDA Natural Resources Conservation Service,  
5 <http://plants.usda.gov/java/imageGallery?category=sciname&txtparm=Fagopyrum&familycategory=all&growthhabit=all&duration=all&origin=all&wetland=all&imagetype=all&artist=all&copyright=all&location=all&stateSelect=all&cite=all&viewsort=25&sort=sciname>).  
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8 <sup>c</sup> Severity of downy mildew was rated on 5 August 2016 on a 0-to-3 scale, where: 0 = no downy mildew symptoms  
9 observed, 1 = <10% of the leaves in a plot had downy mildew, 2 = 10 to 25% of the leaves had downy mildew,  
10 and 3 = >25% of the leaves had downy mildew symptoms.

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