

Virulence characterization of *Puccinia striiformis* f. sp. *tritici* collections from China, Italy, Mexico, and Ecuador

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Introduction

Stripe rust of wheat, caused by *Puccinia striiformis* f. sp. *tritici* (*Pst*), is one of the most important wheat diseases in the world, especially in China, Ecuador, Italy, and Mexico. The objectives of this study were to identify races from wheat stripe rust samples collected from these countries using the set of *Yr* single-gene lines used for differentiating *Pst* races in the United States (Wan and Chen 2014; Wan et al. 2016) and identify virulence frequencies.

Materials and methods

Sampling and obtaining isolates: Stripe rust infected leaves of wheat were collected from China in 2016, Ecuador 2015 and 2016, Italy 2014 and 2016, and Mexico 2015 and 2016. Urediniospore isolates were obtained by inoculating susceptible wheat variety Nugaines as shown in Fig. 1.

Testing on differentials: Isolates of *Pst* were tested on a set of 18 wheat *Yr* single-gene lines (Table 1) used to differentiate *Pst* races in the United States (Wan et al. 2014; Wan et al. 2016). The inoculated plants were placed in a dew chamber at 10°C for 24 h, then moved to a growth chamber with diurnal temperature gradually changing between 4°C at 2:00am to 22°C at 2:00pm with 8h/16h dark/light cycle. Infection type (IT) was recorded based on a 0-9 scale (Fig. 2) 18-22 days after inoculation. An isolate was considered avirulent on a specific differential genotype if it produced IT 0-6 or virulent if it produced IT 7-9. For an isolate showing a new virulence pattern, single-urediniospore isolates were obtained and tested on the set of differentials to confirm the virulence pattern.

Race identification: Based on the virulence/avirulence pattern, an octal code (Table 1) was derived for each isolate and used to determine if the isolate was a previously identified or new race by comparing with the octal codes of previously identified races (Wan et al. 2014; Wan et al. 2016; Wan et al. 2017; M.N. Wang, A.M. Wan, and X.M. Chen, unpublished data). New races were named using the PSTv series (Wan and Chen 2014).

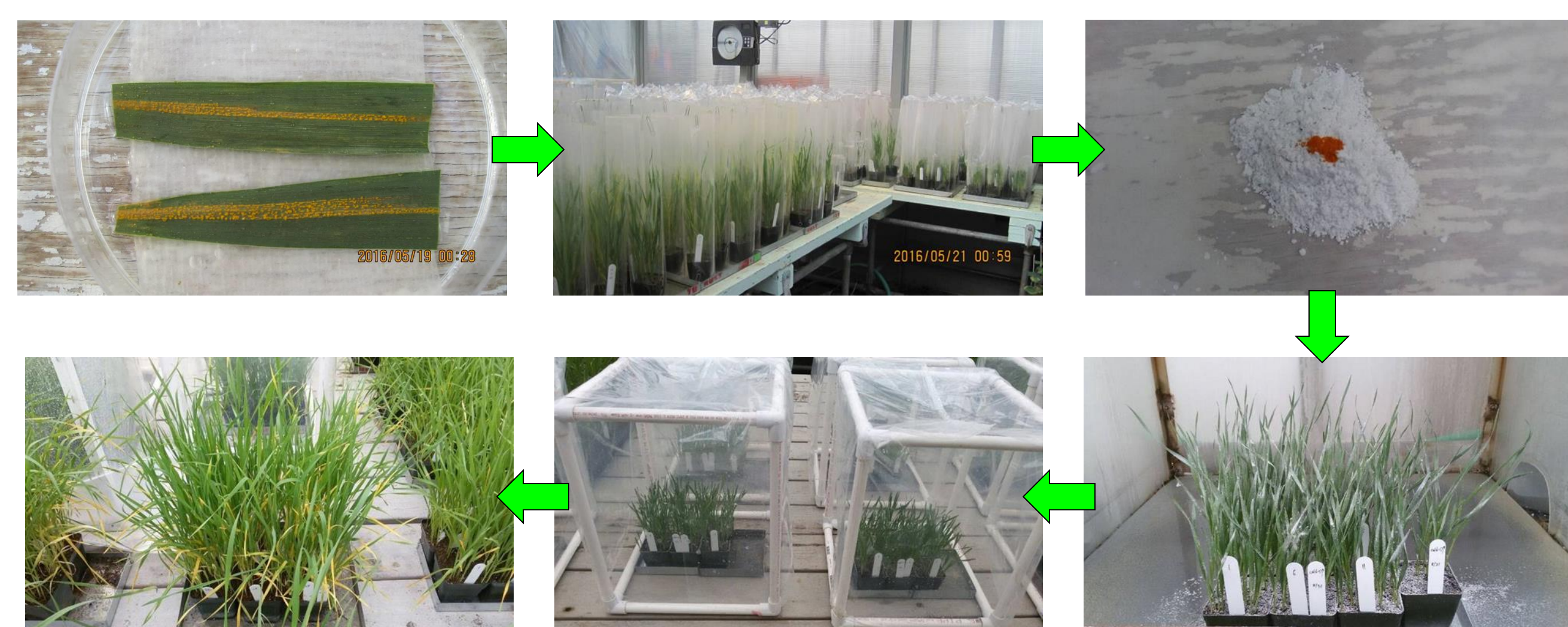


Fig. 1. Procedures for recovering urediniospores and testing on differentials

Table 1. *Yr* single-gene lines used to differentiate *Pst* races and octal codes

Set 1	Yr1	Yr5	Yr6	Octal code	Set 4	Yr24	Yr27	Yr32	Octal code
0	0	0	0	0	0	0	0	0	0
0	0	0	1	1	0	0	1	1	1
0	1	0	0	2	0	1	0	0	2
0	1	1	1	3	0	1	1	1	3
1	0	0	0	4	1	0	0	0	4
1	0	1	5	5	1	0	1	5	5
1	1	0	6	6	1	1	0	6	6
1	1	1	7	7	1	1	1	7	7
Set 2	Yr7	Yr8	Yr9	Octal code	Set 5	Yr43	Yr44	YrSP	Octal code
0	0	0	0	0	0	0	0	0	0
0	0	0	1	1	0	0	1	1	1
0	1	0	2	2	0	1	0	2	2
0	1	1	3	3	0	1	1	3	3
1	0	0	4	4	1	0	0	4	4
1	0	1	5	5	1	0	1	5	5
1	1	0	6	6	1	1	0	6	6
1	1	1	7	7	1	1	1	7	7
Set 3	Yr10	Yr15	Yr17	Octal code	Set 6	YrTr1	YrExp2	Yr76	Octal code
0	0	0	0	0	0	0	0	0	0
0	0	1	1	1	0	0	1	1	1
0	1	0	2	2	0	1	0	2	2
0	1	1	3	3	0	1	1	3	3
1	0	0	4	4	1	0	0	4	4
1	0	1	5	5	1	0	1	5	5
1	1	0	6	6	1	1	0	6	6
1	1	1	7	7	1	1	1	7	7

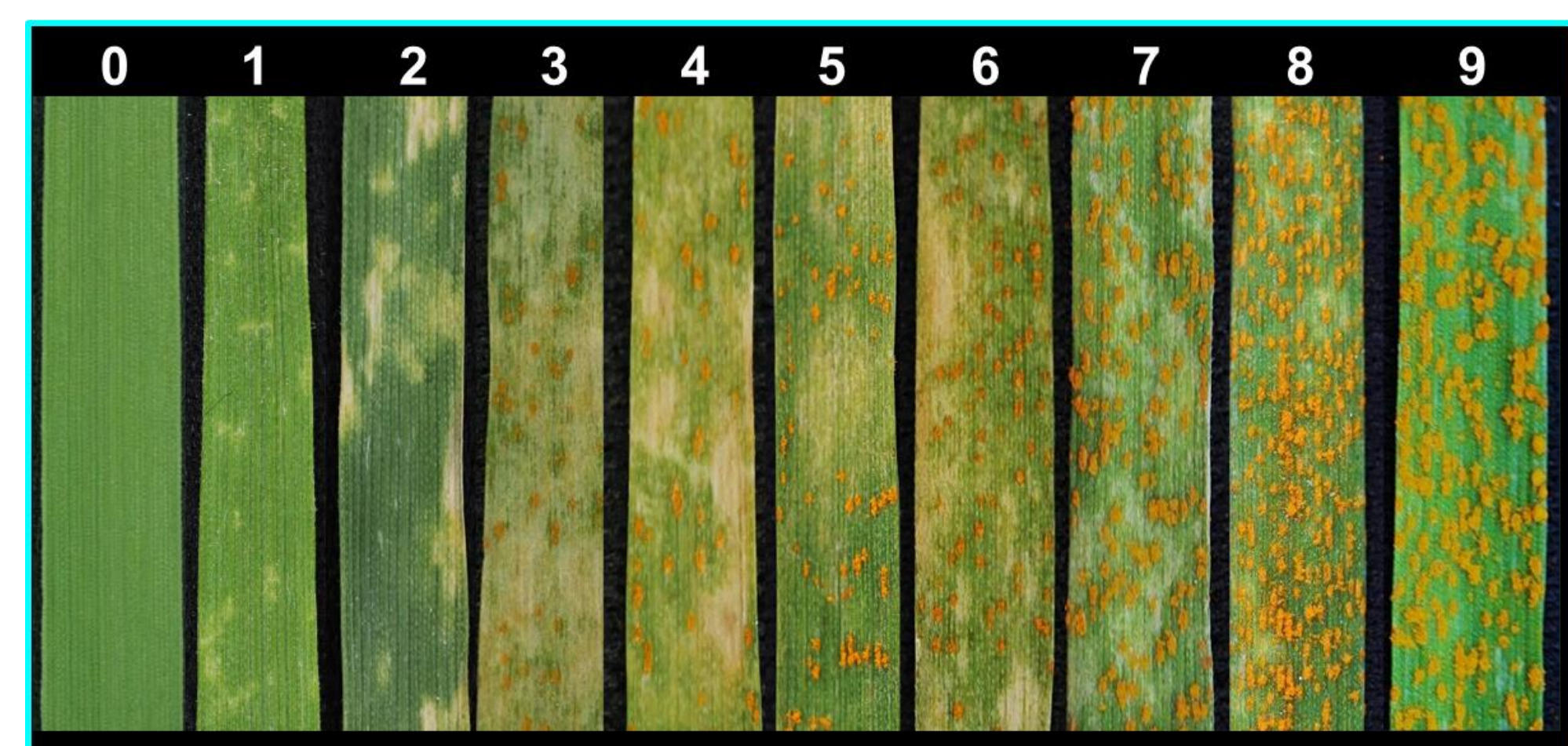


Fig. 2. Infection types produced by *Puccinia striiformis*

References

Wan, A. M., and Chen, X. M. 2014. Virulence characterization of *Puccinia striiformis* f. sp. *tritici* using a new set of *Yr* single-gene line differentials in the United States in 2010. *Plant Dis.* 98:1534-1542.

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Results

Table 2. *Pst* races, frequencies, and distributions in China, Ecuador, Italy, and Mexico

Name	Race	code	Virulence to <i>Yr</i> gene	No. of isolates	Overall freq. (%)	Countries and (No. of isolates)
PSTv-18	000000		/	4	0.9	Ecuador (1), Mexico (3)
PSTv-258	000001		76	1	0.2	China (1)
PSTv-128	000002		Exp2	1	0.2	Italy (1)
PSTv-130	000022		44.Exp2	1	0.2	Italy (1)
PSTv-340	000040		43	1	0.2	Mexico (1)
PSTv-250	000230		27.44.SP	1	0.2	China (1)
PSTv-20	001000		17	2	0.5	Ecuador (2)
PSTv-351	001011		17.SP.76	1	0.2	China (1)
PSTv-315	001024		17.44.Tr1	1	0.2	Ecuador (1)
PSTv-316	001054		17.43.SP.Tr1	1	0.2	Ecuador (1)
PSTv-251	010060		9.43.44	1	0.2	China (1)
PSTv-201	020000		8	1	0.2	Mexico (1)
PSTv-137	020022		8.44.Exp2	7	1.6	Italy (7)
PSTv-136	020062		8.43.44.Exp2	2	0.5	Italy (2)
PSTv-135	021022		8.17.44.Exp2	1	0.2	Italy (1)
PSTv-138	030033		8.9.44.SP.Exp2.76	1	0.2	Italy (1)
PSTv-279	040003		7.Exp2.76	1	0.2	China (1)
PSTv-241	040040		7.43	2	0.5	China (1), Mexico (1)
PSTv-339	041040		17.43	1	0.2	Ecuador (1)
PSTv-248	050040		7.9.43	1	0.2	China (1)
PSTv-256	050070		7.9.43.44.SP	1	0.2	China (1)
PSTv-235	050073		7.9.43.44.SP.Exp2.76	1	0.2	China (1)
PSTv-236	050233		7.9.27.44.SP.Exp2.76	1	0.2	China (1)
PSTv-134	060062		7.8.43.44.Exp2	1	0.2	Italy (1)
PSTv-133	061062		7.8.17.43.44.Exp2	3	0.7	Italy (3)
PSTv-132	061462		7.8.17.24.43.44.Exp2	1	0.2	Italy (1)
PSTv-347	064060		7.8.43.44	2	0.5	Italy (2)
PSTv-262	071284		7.8.9.17.27.43.44.Tr1	1	0.2	Mexico (1)
PSTv-255	100225		6.44.Tr1.76	1	0.2	China (1)
PSTv-282	100722		6.43.44.SP.Exp2	1	0.2	China (1)
PSTv-246	110071		6.9.43.44.SP.76	1	0.2	China (1)
PSTv-346	130000		6.8.9	1	0.2	Mexico (1)
PSTv-183	140022		6.7.44.Exp2	1	0.2	Mexico (1)
PSTv-310	140062		6.7.43.44.Exp2	5	1.1	Ecuador (5)
PSTv-343	140242		6.7.27.43.Exp2	1	0.2	Mexico (1)
PSTv-221	140262		6.7.27.43.44.Exp2	3	0.7	Ecuador (3)
PSTv-313	140272		6.7.27.43.44.SP.Exp2	1	0.2	Ecuador (1)
PSTv-342	141062		6.7.17.43.44.Exp2	1	0.2	Ecuador (1)
PSTv-311	141072		6.7.17.43.44.SP.Exp2	1	0.2	Ecuador (1)
PSTv-341	141262		6.7.17.27.43.44.Exp2	9	2.0	Ecuador (9)
PSTv-345	150002		6.7.9.Exp2	1	0.2	China (1)
PSTv-271	150023		6.7.9.44.Exp2.76	1	0.2	China (1)
PSTv-257	150051		6.7.9.43.76	1	0.2	China (1)
PSTv-261	150061		6.7.9.43.44.76	1	0.2	China (1)
PSTv-260	150071		6.7.9.27.43.44.SP.76	1	0.2	China (1)
PSTv-280	150073		6.7.9.43.44.SP.Exp2.76	1	0.2	China (1)
PSTv-28	151022		6.7.9.17.44.Exp2	1	0.2	Mexico (1)
PSTv-131	160062		6.7.8.43.44.Exp2	1	0.2	Italy (1)
PSTv-78	160262		6.7.8.27.43.44.Exp2	2	0.5	Mexico (2)
PSTv-102	160286		6.7.8.27.43.44.Tr1.Exp2	1	0.2	Mexico (1)
PSTv-30	170026		6.7.8.9.44.Tr1.Exp2	1	0.2	Mexico (1)
PSTv-259	170072		6.7.8.9.43.44.SP.Exp2	1	0.2	China (1)
PSTv-272	170222		6.7.8.9.44.Exp2	1	0.2	Mexico (1)
PSTv-198	170262		6.7.8.9.27.43.44.Exp2	13	2.9	China (1), Mexico (12)
PSTv-36	170266		6.7.8.9.27.43.44.Tr1.Exp2	5	1.1	Mexico (5)
PSTv-276	170544		6.7.8.9.24.32.43.Tr1	1	0.2	Mexico (1)
PSTv-52	171262		6.7.8.9.17.27.43.44.Exp2	22	5.0	Ecuador (1), Mexico (21)
PSTv-283	171264		6.7.8.9.17.27.43.44.Tr1	1	0.2	Mexico (1)
PSTv-37	171266		6.7.8.9.17.27.43.44.Tr1.Exp2	51	11.5	Ecuador (1), Mexico (50)
PSTv-306	171277		6.7.8.9.17.27.43.44.SP.Tr1.Exp2.76	1	0.2	Mexico (1)
PSTv-344	171744		6.7.8.9.10.17.24.27.32.43.44.Tr1	1	0.2	Mexico (1)
PSTv-109	174266		6.7.8.9.10.27.43.44.Tr1.Exp2	1	0.2	Mexico (1)
PSTv-263	400040		1.43	1	0.2	China (1)
PSTv-238	410220		1.9.27.44	1	0.2	China (1)
PSTv-129	411022		1.9.17.44.Exp2	1	0.2	Italy (1)
PSTv-323	430200		1.8.9.27	1	0.2	Ecuador (1)
PSTv-140	450021		1.7.9.44.76	1	0.2	China (1)
PSTv-121	450031		1.7.9.44.SP.76	1	0.2	Italy (1)
PSTv-265	450033		1.7.9.44.SP.Exp2.76	1	0.2	China (1)
PSTv-284	450231		1.7.9.27.44.SP.76	1	0.2	China (1)
PSTv-309	470220		1.7.8.9.27.44	1	0.2	Ecuador (1)
PSTv-243	470270		1.7.8.9.27.43.44.SP	1	0.2	China (1)
PSTv-321	501231		1.6.17.27.44.SP.76	1	0.2	Mexico (1)
PSTv-53	510011		1.6.9.SP.76	6	1.4	China (1), Mexico (5)
PSTv-281	510033		1.6.9.44.SP.Exp2.76	1	0.2	China (1)
PSTv-252	511030		1.6.9.17.44.SP	1	0.2	Mexico (1)
PSTv-4	511211		1.6.9.17.27.SP.76	2	0.5	Ecuador (1), Mexico (1)
PSTv-240	530003		1.6.7.Exp2.76	1	0.2	China (1)
PSTv-338	530211		1.6.8.9.27.SP.76	1	0.2	Mexico (1)
PSTv-348	540023		1.6.7.44.Exp2.76	1	0.2	China (1)
PSTv-253	540043		1.6.7.43.Exp2.76	1	0.2	China (1)
PSTv-266	540073		1.6.7.17.43.44.SP.Exp2.76	1	0.2	China (1)
PSTv-226	540273		1.6.7.27.43.44.SP.Exp2.76	4	0.9	China (4)
PSTv-329	541262		1.6.7.17.27.43.44.Exp2	2	0.5	Ecuador (2)
PSTv-254	541273		1.6.7.17.27.43.44.SP.Exp2.76	1	0.2	China (1)
PSTv-234	550003		1.6.7.9.Exp2.76	1	0.2	China (1)
PSTv-350	550013		1.6.7.9.SP.Exp2.76	1	0.2	China (1)
PSTv-269	550021		1.6.7.9.44.Exp2.76	2	0.5	China (2)
PSTv-231	550031		1.6.7.9.44.SP.76	3	0.7	China (3)
PSTv-270	550033		1.6.7.9.44.SP.Exp2.76	2	0.5	China (2)
PSTv-267	550035		1.6.7.9.44.SP.Tr1.76	3	0.7	China (3)
PSTv-230	550071		1.6.7.9.43.44.SP.76	2	0.5	China (2)
PSTv-232	550072		1.6.7.9.43.44.SP.Exp2	11	2.5	China (3), Italy (8)
PSTv-125	550073		1.6.7.9.43.44.SP.Exp2.76	23	5.2	China (14), Italy (9)
PSTv-228	550233		1.6.7.9.27.44.SP.Exp2.76	5	1.1	China (5)
PSTv-314	550262		1.6.7.9.27.43.44.Exp2	8	1.8	Ecuador (8)
PSTv-71	550263		1.6.7.9.27.43.44.Exp2.76	1	0.2	China (1)
PSTv-349	550271		1.6.7.9.27.43.44.SP.76	1	0.2	China (1)
PSTv-227	550272		1.6.7.9.27.43.44.SP.Exp2	4	0.9	China (4)
PSTv-225	550273		1.6.7.9.27.43.44.SP.Tr1.Exp2.76	43	9.7	China (43)
PSTv-192	550277		1.6.7.9.27.43.44.SP.Tr1.Exp2.76	2	0.5	China (1), Italy (1)
PSTv-268	551001		1.6.7.9.17.76	1	0.2	China (1)
PSTv-205	551032		1.6.7.9.17.44.SP.Exp2	1	0.2	Italy (1)
PSTv-336	551052		1.6.7.9.17.43.SP.Exp2	4	0.9	Italy (4)
PSTv-334	551070		1.6.7.9.17.43.44.SP	6	1.4	Italy (6)
PSTv-127	551072		1.6.7.9.17.43.44.SP.Exp2	65	14.7	Italy (65)
PSTv-278	551073		1.6.7.9.17.43.44.SP.Exp2.76	11	2.5	China (2), Italy (9)
PSTv-335	551076		1.6.7.9.17.43.44.SP.Tr1.Exp2	1	0.2	Italy (1)
PSTv-274	551233		1.6.7.9.17.27.44.SP.76	1	0.2	China (1)
PSTv-106	551262		1.6.7.9.17.27.43.44.Exp2	2	0.5	Ecuador (2)
PSTv-175	551263		1.6.7.9.17.27.43.44.Exp2.76	1	0.2	Italy (1)
PSTv-333	551267		1.6.7.9.17.27.43.44.Tr1.Exp2			