The Pharma Innovation Journal 2022; 11(7): 3477-3482

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; 11(7): 3477-3482

www.thepharmajournal.com
Received: 09-05-2022
Accepted: 10-06-2022

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Screening of vegetable pea germplasm for resistance against downy mildew caused *Peronospora viciae* f. sp. *pisi* Sydow

Jagadeesh Bathula and Rajesh Pratap Singh

Abstract
Downy mildew caused by *Peronospora viciae* f. sp. *pisi* results heavy losses in the yield and quality of green pods in vegetable pea crop. An experiment on the screening of various vegetable pea genotypes was conducted at Pantnagar, Uttarakhand conditions. Germplasm comprising 89 accessions of vegetable pea collected from different sources were screened for disease resistance against downy mildew under natural epiphytotic conditions for 2 years. Based on the data on two consecutive years, among the 89 accessions screened, PS-11, PCPGR-6091 and Selection-23 were found to be resistant with lowest Percent Disease Index (PDI) and Area under Disease Progress Curve (AUDPC). Multi frozen, Pila Lubix, Little Marvel, Lincoln, EFL-9, PSM-3, Pant Upahar were moderately resistant, rest of the germplasm found to be moderately susceptible and Arkel was found be susceptible with highest PDI and AUDPC to downy mildew.

Keywords: Vegetable pea, *Peronospora viciae*, downy mildew, screening, germplasm

Introduction
Vegetable pea (*Pisum sativum* var. *hortense* L.) also called as garden pea is one of the important cool season vegetable crops belongs to family Leguminosae, grown all over the world for fresh and processed forms. India is the highest vegetable pea producing country in the world. In India, it is grown as winter season vegetable in the Central and Northern plains and as a summer and autumn-winter crop in the hilly regions. It occupies an area of about 5.68 lakh hectares with annual production and productivity of 57.91 lakh metric tons and 10.0 metric tons per hectare respectively (Anon, 2020). In Uttarakhand region, vegetable pea holds an important position as vegetable grown over an area of 13.09 thousand hectare with an annual production of 93.40 thousand metric tons and productivity of 7.14 tons/ha (Anon, 2020).
Vegetable pea is affected by several diseases but downy mildew caused by oomycete *Peronospora viciae* f. sp. *pisi* is very devastating under cool, moist environmental conditions. Symptoms of downy mildew in pea can be either systemic or local. Systemic infection, which is the more severe form of the disease, results in stunting and distortion of the plants, usually kill the plants before flowering. The pathogen produces abundant inoculum in the form of sporangia on infected plant surfaces. Foliar infections are usually local, and begin on the lower parts of leaves. Infected leaves turn yellow and die if weather is cool and damp. Stems may be distorted and stunted.
The pathogen may also infect and sporulate on the inflorescences and tendrils. Pod infection can occur under conditions of high relative humidity even in the absence of foliar infection. Infected pods become deformed and exhibit surface blistering. Optimal conditions for downy mildew development consist of cool humid weather, in contrast to the warm and dry conditions required for infection by powdery mildew. Secondary spread of the disease occurs solely by means of sporangia (Fallon and Sutherland, 1996). The present experiment was designed to identify the vegetable pea germplasm lines resistant to downy mildew disease and we assume that the information generated in this experiment could greatly assist in the conservation of vegetable pea germplasm and its efficient utilization in breeding programs.

Materials and Methods
Present experiment was carried at Vegetable Research Centre, GBPUAT, Pantnagar,

Uttarakhand for two consecutive years (*Rabi* 2017-18 and 2018-19). A total of 89 Vegetable pea germplasm accessions were obtained from all available sources from Pantnagar Centre for Plant Genetic Resources (PCPGR) GBPUAT, Pantanagr, Vegetable Research Centre (VRC), Pantnagar and from Department of Vegetable Science, Indian Agriculture Research Institute (IARI), New Delhi.

The collected germplasm accessions were screened under natural epiphytotic conditions. Two rows of each accession were sown. Experiment was replicated twice in 2 m row length at 15 cm row spacing with susceptible check Arkel. After appearance of symptoms, each plant was scored using 0-5 modified disease rating scale given by Davidson et al. (2011). [3], and subsequent observations were recorded at 10 days interval. The Percent Disease Index (PDI) was calculated by using following formulae given by Wheeler (1969). [8]. Later, based on the pooled PDI, germplasm was categorized into different groups (Table 4).

$$\text{Per cent Disease Index (PDI)} = \frac{\text{Total sum of numerical ratings}}{\text{Total No. of leaves examined x Maximum disease grade}} \text{x100}$$

Table 1: Disease severity scale with the description

Rating	Description	Reaction
0	No lesions, all leaves disease free.	Immune
1	Sporadic lesions, with less than one lesion per leaf. Limited sporulation. (1-10% sporulation)	Resistant
2	Up to two lesions per leaf, lesions limited to outer/lower leaves. (10.1-25% sporulation)	Moderately Resistant
3	Three to ten lesions per leaf, lesions on outer/lower leaves. Disease spreading to wrapper/upper leaves. (25.1-50% sporulation)	Moderately Susceptible
4	More than 10 lesions per leaf, many lesions on outer/lower leaves. Moderate number of lesions on wrapper/upper leaves. (50.1-75% sporulation)	Susceptible
5	Severe plant infection, merging of lesions, heavy sporulation and/or large number of necrotic areas. (> 75% sporulation)	Highly Susceptible

The following parameters were calculated to study the disease progression.

AUDPC (A) value

Area under Disease Progressive Curve (AUDPC or A value) of downy mildew in vegetable pea will be quantified by using the following formulae given by Nagarajan and Muralidharan, 1995 [5].

$$A = \sum_{i=1}^{k} {}^{1}/_{2} (S_i + S_{i-1})d$$

Where, S_i = disease index at the end i, k = number of successive evaluations of disease and d = interval between two evaluations.

Apparent rate of infection ('r')

The apparent rate of infection was calculated by using following formulae given by Van der plank, 1968 [7].

$$r = \frac{2.303}{t_2 - t_1} log \frac{x_2(1 - x_1)}{x_1(1 - x_2)}$$

Where, r = apparent rate of infection in logarithmic phase, x_1 = disease index at initial time (t_1) and x_2 = disease index at subsequent time (t_2).

Statistical analysis

Experimental data were analyzed using standard analysis of variance (ANOVA) using computer software package IBM SPSS Statistics v. 23 (Statistical Package for the Social Sciences)

Results and Discussion

A total of 89 genotypes were screened under epiphytotic field condition over two seasons. Among the different genotypes during 2017-2018, the disease severity (PDI) ranged from 8.7 to 57.7 and was highest in Arkel (57.7), followed by PB-29 (46.9) and PSM-5 (45.3) and lowest in PCPGR-6091 (8.7) followed by Selection-23 (10.0) and PSM-11 (10.2). AUDPC was ranged from 86.0 to 560.8 and maximum AUDPC value was observed in Arkel (560.8), followed by PB-29 (453.3), Boach Selection (446.7) and least AUDPC (86.0) was observed in PCPGR-6091 followed by Selection-23 (97.5), PSM-11 (100). Apparent rate of infection was maximum in Anuyogi (0.287) followed by Pant Uphar (0.218) whereas Boasch Selection showed lowest infection rate (0.049) followed by Arka Ajith (0.055) (Table 2).

During 2018-2019, the disease severity (PDI) ranged from 8.5 to 54.5 and highest (54.5) in Arkel, followed by 44.2 per cent in PB-29 and 42.3 per cent in PSM-5 and lowest (8.5) in PCPGR-6091 followed by 9.8 in PSM-11 and 10.0 in Selection-23. Maximum AUDPC value was observed in Arkel (555.8), followed by PB-29 (448.3), Boach Selection (441.7) and least AUDPC (82.5) was observed in PCPGR-6091 followed by Selection-23 (99.2), PSM-11 (95.0). Apparent rate of infection was maximum in Anuyogi (0.413) followed by PG3 (0.366) whereas Arka Ajith showed lowest infection rate (0.041) (Table 2).

Pooled data on the 89 total germplasm accessions revealed that, the per cent disease severity was maximum in Arkel (56.1) followed by PB-29 (45.4) and minimum in PCPGR-6091 (8.6) followed by PSM-11 (10.0) and Selection-23 (10.0). Maximum AUDPC value was observed in Arkel (558.3) followed by PB-29 (450.8), while PCPGR-6091 scored least AUDPC (84.3) followed by PSM-11 (97.5). Apparent rate of infection was maximum in Anuyogi (0.350) whereas Boasch Selection showed lowest infection rate (0.045) (Table 3).

Based on the two years data on 89 total germplasm accessions, germplasm was grouped into different categories on the basis of PDI, the per cent disease severity was maximum in Arkel followed by PB-29 and minimum in PCPGR-6091 followed by PSM-11 (Table 4).

Among all the genotypes, PCPGR-6091, PSM-11 and Selection-23 were found to be the most suitable genotype with minimum PDI. These results corroborate with the findings of Bhushan et al. (2013) where P-89 was found to be the most suitable genotype among all the genotypes with minimum downy mildew incidence (10.3%) under mid hill conditions. The rate of resistance varied independently among vegetable pea genotypes which shown moderate resistance. These results corroborate with the findings of Stegmark (2009) that the rate of resistance of pods and leaves varied independently among

pea genotypes. Three genotypes are found to be higher rate of resistance against downy mildew and seven genotypes were found to show moderate resistance with varied rate of resistance. These results corroborate with the findings of Kumar et al. (1994) where two genotypes had a higher rate of resistance and described the pea varieties Pant P8, HUP 8063, KPMR 22 to possess varied levels of partial resistance.

Table 2: Screening of germplasm against downy mildew of vegetable pea 2017-18 and 2018-2019

Sl. No.	Germplasm	2017-18			2018-19		
		Disease severity	'A' Value	'r' Value	Disease severity	'A' Value	'r' Value
1	Multi frozen	22.5	210.0	0.171	20.5	188.3	0.220
2	PG 3	29.3	270.0	0.162	29.3	243.3	0.366
3	PSM 11	10.2	100.0	0.110	9.8	95.0	0.190
4	Pila Lubix	11.3	111.7	0.097	11.3	106.7	0.272
5	Meethi Phali	28.2	261.7	0.152	27.2	245.0	0.209
6	Little Marvel	11.8	115.0	0.142	11.7	110.0	0.257
7	Lincoln	25.2	246.8	0.077	23.2	235.0	0.024
8	PMR 8	28.6	278.0	0.083	26.0	253.3	0.084
9	VP 7802	34.2	337.0	0.062	32.2	311.7	0.083
10	Selection-03	34.8	330.8	0.104	33.8	315.8	0.127
11	MLP-9	38.2	351.7	0.133	37.2	340.0	0.145
12	VP-8902	30.7	290.0	0.118	29.7	260.0	0.246
13	GC-241	33.8	320.0	0.110	31.8	300.0	0.120
14	PCPGR-6091	8.7	86.0	0.099	8.5	82.5	0.191
15	EFL-9	25.5	245.0	0.107	24.5	223.3	0.206
16	Selection-23	10.0	97.5	0.148	10.0	99.2	0.079
17	PP-79	35.5	330.0	0.129	29.8	288.3	0.089
18	Star Corset	26.3	248.3	0.134	25.3	230.0	0.208
19	VP-0588-2	26.2	238.3	0.197	25.2	218.3	0.307
20	Corbrettee	19.7	181.7	0.214	18.7	171.7	0.235
21	UD-3	29.8	285.0	0.105	28.8	263.3	0.177
22	NDVP-5	38.3	361.7	0.105	37.3	340.0	0.150
23	EC-741770	30.5	286.7	0.127	29.5	265.0	0.202
24	Supralaska	25.7	245.0	0.117	24.7	228.3	0.175
25	Sampoorna	27.8	270.0	0.087	26.8	246.7	0.176
26	Bbs-p-8-KS-126	34.7	338.3	0.072	33.7	316.7	0.118
27	VP-3	37.2	355.0	0.093	36.2	330.0	0.151
28	PP-14	38.7	360.0	0.120	37.7	341.7	0.155
29	RAU-23	37.2	340.0	0.145	36.2	311.7	0.236
30	VRP-2	32.0	298.3	0.134	31.0	278.3	0.195
31	PM-2	34.2	330.0	0.084	33.2	310.0	0.127
32	P-83	30.7	280.0	0.170	29.7	266.7	0.200
33	Sutton Early	30.2	281.7	0.137	29.2	268.3	0.164
34	Victory Progress	29.0	263.3	0.186	28.0	240.0	0.305
35	L-116	30.5	288.3	0.118	29.5	265.0	0.202
36	VP-6379	37.0	355.0	0.089	36.0	331.7	0.139
37	Anuyogi	28.8	248.3	0.287	27.8	228.3	0.413
38	Selection-14-3-2	33.0	303.3	0.151	32.0	283.3	0.213
39	GC-242	42.2	403.3	0.086	41.2	383.3	0.115
40	Barpeena	38.3	371.7	0.076	37.3	343.3	0.138
41	Monoa Sugar	30.8	291.7	0.117	29.8	286.7	0.097
42	PH-2	28.3	266.7	0.131	27.3	261.7	0.108
43	Alderman Dwarf	34.5	331.7	0.090	33.5	326.7	0.074
44	VRP-2	40.7	396.7	0.069	39.7	391.7	0.058
45	P-88	40.2	391.7	0.069	39.2	386.7	0.058
46	P-6560-2	42.7	418.3	0.063	41.0	413.3	0.053
47	P-2007	43.8	428.3	0.065	41.8	423.3	0.056
48	PSM-4	37.3	360.0	0.083	34.7	355.0	0.070
49	PP-42	27.8	260.0	0.145	24.2	255.0	0.120
50	Corzee	42.7	418.3	0.063	41.0	413.3	0.053
51	Boach selection	44.8	446.7	0.049	44.5	441.7	0.040
52	GP-2011-245	38.3	371.7	0.076	36.0	366.7	0.064
53	PB-29	46.5	453.3	0.066	44.2	448.3	0.058
54	Waver Plus	38.7	368.3	0.094	35.0	363.3	0.082
55	Vl-40	42.2	413.3	0.063	40.5	408.3	0.053
56	P-185	40.0	390.0	0.070	38.0	385.0	0.058
57	Royal	34.8	335.0	0.089	32.2	330.0	0.073
58	Frenzy	37.0	356.7	0.084	34.3	351.7	0.070

59	Midivart	40.8	403.3	0.057	39.8	398.3	0.046
60	Pant Upahar	28.3	253.3	0.218	22.3	248.3	0.194
61	GC-245	38.5	376.7	0.067	36.8	371.7	0.055
62	Ani Variety	37.3	368.3	0.059	36.3	363.3	0.046
63	Arkel	57.7	560.8	0.064	54.5	555.8	0.058
64	PSM-3	27.7	266.7	0.097	25.7	261.7	0.072
65	Azad Pea-3	33.2	326.8	0.062	33.2	326.7	0.029
66	PSM-5	45.3	438.3	0.074	42.3	433.3	0.065
67	VL-7	34.8	333.3	0.095	31.8	328.3	0.079
68	E-6	34.3	331.7	0.084	32.0	326.7	0.068
69	GP-57	33.5	321.7	0.092	30.8	316.7	0.076
70	GP-272	34.0	325.0	0.097	31.0	320.0	0.081
71	GP-36	34.2	323.3	0.109	30.5	318.3	0.093
72	GP-90	39.7	381.7	0.083	36.7	376.7	0.071
73	GP-38	36.2	345.0	0.096	32.8	340.0	0.082
74	GP-77	35.0	330.0	0.112	31.0	325.0	0.097
75	GP-89	34.8	340.0	0.072	33.2	335.0	0.057
76	GP-61	35.0	341.7	0.072	33.3	336.7	0.057
77	GP-17	37.2	363.3	0.069	35.5	358.3	0.055
78	GP-248	32.7	311.7	0.102	29.7	306.7	0.084
79	GP-525	33.5	320.0	0.099	30.5	315.0	0.082
80	VP-625	37.0	351.7	0.099	33.3	346.7	0.086
81	VP-438-2	35.8	343.3	0.092	32.8	338.3	0.077
82	Snap Pea Sel-1	36.0	345.0	0.091	33.0	340.0	0.077
83	Pusa Prabhal	35.5	343.3	0.082	33.2	338.3	0.067
84	VL Matar-10	35.0	338.3	0.083	32.7	333.3	0.068
85	DPP-11	33.8	330.0	0.073	32.2	325.0	0.057
86	VRP-7	35.3	348.3	0.061	34.3	343.3	0.046
87	Arka Ajith	36.5	361.7	0.055	35.8	356.7	0.041
88	Meg-2	36.3	351.7	0.080	34.0	346.7	0.066
89	UD-2	37.2	363.3	0.069	35.5	358.3	0.055
	CD at 5%	7.38	-	-	7.62	-	-
	CV	21.48	-	-	22.75	-	-

'A' = Area under disease progressive curve, 'r' = Apparent rate of infection

Table 3: Screening of germplasm against downy mildew of vegetable pea Pooled

Sl. No.	Germplasm	Disease severity	'A' Value	'r' Value	Reaction group
1	Multi freezon	21.5	199.2	0.196	MR
2	PG 3	29.3	256.7	0.264	MS
3	PSM 11	10.0	97.5	0.150	R
4	Pila Lubix	11.3	109.2	0.185	MR
5	Meethi Phali	27.7	253.4	0.181	MS
6	Little Marvel	11.8	112.5	0.200	MR
7	Lincoln	24.2	240.9	0.051	MR
8	PMR 8	27.3	265.7	0.084	MS
9	VP 7802	33.2	324.4	0.073	MS
10	Selection-03	34.3	323.3	0.116	MS
11	MLP-9	37.7	345.9	0.139	MS
12	VP-8902	30.2	275.0	0.182	MS
13	GC-241	32.8	310.0	0.115	MS
14	PCPGR-6091	8.6	84.3	0.145	R
15	EFL-9	25.0	234.2	0.157	MR
16	Selection-23	10.0	98.4	0.114	R
17	PP-79	32.7	309.2	0.109	MS
18	Star Corset	25.8	239.2	0.171	MS
19	VP-0588-2	25.7	228.3	0.252	MS
20	Corbrettee	19.2	176.7	0.225	MR
21	UD-3	29.3	274.2	0.141	MS
22	NDVP-5	37.8	350.9	0.128	MS
23	EC-741770	30.0	275.9	0.165	MS
24	Supralaska	25.2	236.7	0.146	MS
25	Sampoorna	27.3	258.4	0.132	MS
26	Bbs-p-8-KS-126	34.2	327.5	0.095	MS
27	VP-3	36.7	342.5	0.122	MS
28	PP-14	38.2	350.9	0.138	MS
29	RAU-23	36.7	325.9	0.191	MS

30	VRP-2	31.5	288.3	0.165	MS
31	PM-2	33.7	320.0	0.106	MS
32	P-83	30.2	273.4	0.185	MS
33	Sutton Early	29.7	275.0	0.151	MS
34	Victory Progress	28.5	251.7	0.246	MS
35	L-116	30.0	276.7	0.160	MS
36	VP-6379	36.5	343.4	0.114	MS
37	Anuyogi	28.3	238.3	0.350	MS
38	Selection-14-3-2	32.5	293.3	0.182	MS
39	GC-242	41.7	393.3	0.101	MS
40	Barpeena	37.8	357.5	0.107	MS
41	Monoa Sugar	30.3	289.2	0.107	MS
42	PH-2	27.8	264.2	0.120	MS
43	Alderman Dwarf	34.0	329.2	0.082	MS
44	VRP-2	40.2	394.2	0.064	MS
45	P-88	39.7	389.2	0.064	MS
46	P-6560-2	41.9	415.8	0.058	MS
47	P-2007	42.8	425.8	0.061	MS
48	PSM-4	36.0	357.5	0.077	MS
49	PP-42	26.0	257.5	0.133	MS
50	Corzee	41.9	415.8	0.058	MS
51	Boach selection	44.7	444.2	0.045	MS
52	GP-2011-245	37.2	369.2	0.070	MS
53	PB-29	45.4	450.8	0.062	MS
54	Waver Plus	36.9	365.8	0.088	MS
55	Vl-40	41.4	410.8	0.058	MS
56	P-185	39.0	387.5	0.064	MS
57	Royal	33.5	332.5	0.081	MS
58	Frenzy	35.7	354.2	0.077	MS
59	Midivart	40.3	400.8	0.052	MS
60	Pant Upahar	25.3	250.8	0.206	MR
61	GC-245	37.7	374.2	0.061	MS
62	Ani Variety	36.8	365.8	0.053	MS
63	Arkel	56.1	558.3	0.061	S
64	PSM-3	26.7	264.2	0.085	MR
65	Azad Pea-3	33.2	326.8	0.046	MS
66	PSM-5	43.8	435.8	0.070	MS
67	VL-7	33.3	330.8	0.087	MS
68	E-6	33.2	329.2	0.076	MS
69	GP-57	32.2	319.2	0.084	MS
70	GP-272	32.5	322.5	0.089	MS
71	GP-36	32.4	320.8	0.101	MS
72	GP-90	38.2	379.2	0.077	MS
73	GP-38	34.5	342.5	0.089	MS
74	GP-77	33.0	327.5	0.105	MS
75	GP-89	34.0	337.5	0.065	MS
76	GP-61	34.2	339.2	0.065	MS
77	GP-17	36.4	360.8	0.062	MS
78	GP-248	31.2	309.2	0.093	MS
79	GP-525	32.0	317.5	0.091	MS
80	VP-625	35.2	349.2	0.093	MS
81	VP-438-2	34.3	340.8	0.085	MS
82	Snap Pea Sel-1	34.5	342.5	0.084	MS
83	Pusa Prabhal	34.4	340.8	0.075	MS
84	VL Matar-10	33.9	335.8	0.076	MS
85	DPP-11	33.0	327.5	0.065	MS
86	VRP-7	34.8	345.8	0.054	MS
87	Arka Ajith	36.2	359.2	0.048	MS
88	Meg-2	35.2	349.2	0.073	MS
89	UD-2	36.4	360.8	0.062	MS
	CD at 5%	7.50	-	-	-
	CV	22.10	-	-	-

R = Resistant; MR = Moderately Resistant; MS = Moderately Susceptible, S = Susceptible, HS = Highly Susceptible

Table 4: Grouping of Vegetable pea germplasm screened against downy mildew (Pooled data of Rabi 2018 and 2019)

Scale	Germplasm accessions	Reaction
1	PS-11, PCPGR-6091, Selection-23	R
2	Multi frozen, Pila Lubix, Little Marvel Lincoln, EFL-9, PSM-3, Pant Upahar	MR
3	PP-79, Star Corset, VP-0588-2, Corbrettee, UD-3, NDVP-5, EC-741770 Supralaska, Sampoorna, Bbs-p-8-KS-126, VP-3, PP-14, RAU-23, VRP-2, PSM-2, P-83, Sutton Early, Victory, Progress, L-116, VP-6379, Anuyogi, Selection-14-3-2, GC-242, Barpeena, Monoa Sugar, PH-2, Alderman Dwarf, VRP-2, P-88, P-6560-2, P-2007, PSM-4, PP-42, Corzee, Boach selection, GP-2011-245, PB-29, Waver Plus, Vl-40, P-185, Royal, Frenzy, Midivart, GC-245, Ani Variety, PSM-5, VL-7, E-6, GP-57, GP-272, GP-36, GP-90, GP-38, GP-77, GP-89, GP-61, GP-17, GP-248, GP-525, VP-625, VP-438-2, Snap Pea Sel-1, Pusa Prabhal, VL Matar-10, DPP-11, VRP-7, Arka Ajith, Meg-2, UD-2	MS
4	Arkel	S

Conclusion

Among 89 genotypes screened none of them were free from downy mildew during both the seasons. Only two germplasm accessions viz. PSM-11, PCPGR-6091and Selection-23 were found to be resistant with less per cent disease severity (PDI). Maximum numbers of genotypes (78) fall under the category of moderately susceptible, Genotypes viz., Multi frozen, Pila Lubix, Little Marvel, Lincoln, EFL-9, PSM-3, Pant Upahar found to be moderately resistant downy mildew of vegetable pea and Arkel as susceptible.

Acknowledgements

Authors are thankful to Pantnagar Centre for Plant Genetic Resources GBPUAT, Pantanagr and Department of Vegetables, Indian Agriculture Research Institute (IARI), New Delhi for providing germplasms.

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