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SHORT COMMUNICATION

Identification of resistance sources against frogeye leaf spot (FLS) disease of soybean caused by *Cercospora sojina* under hot spot conditions of Uttarakhand hills

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Abstract
Frogeye leaf spot of soybean [*Glycine max* (L.) Merr.] caused by *Cercospora sojina* Hara is an important disease that causes significant yield loss. The present investigation was carried out to identify the resistance source(s) against frogeye leaf spot (FLS) in soybean at Experimental Farm, Hawalbagh, ICAR–VPKAS, Almora, Uttarakhand, India, considered as hot spot for FLS, during *kharif*, 2018 and 2019. Forty five genotypes along with two susceptible checks were evaluated against FLS. Per cent Disease Index (PDI) varied from 1.9 to 78.8%. Out of 45 genotypes screened, none was Immune, 24.44% were highly resistant, 64.44% were moderately resistant, and 15.55% were moderately susceptible to FLS disease. Eleven genotypes *i.e.* NRC 88, VS 2004–9, VS 2005–40, VS 2006–17, DSB 11, NRC 84, AMS-MB-5-19, VLS 86, Himso 1685, MACS 1407, and MACS 1442 were found to be highly resistant (PDI 1.9% to 10.9%) with VS 2005–40 and MACS 1442 showed minimum and maximum PDI, respectively. These resistant genotypes can be used as source of donors for evolving resistant varieties against frogeye leaf spot disease in future breeding programme.

Keywords Frogeye leaf spot · *Glycine max* · Resistance · Hot spot · Uttarakhand hills

Soybean (*Glycine max* L.) is the unique grain legume globally known for its dual purpose use as pulse and oilseed containing 38–44% protein and 18–22% oil. Soybean also finds place as the key component in a diverse range of industrial products like solvents, adhesives, inks, lubricants and insulating foams etc. In a large section of vegetarian people in country like India, soybean plays an important role as a rich source of protein. Soybean is cultivated as a *kharif* season crop in India and during 2016–17, it has occupied 10.97 million ha area with total production of 10.99 million tons whereas the productivity stand of 1002 kg/ha in the country. Among states, Madhya Pradesh ranked first in area as well as in production and covers of 54.01 lakh ha area with the average productivity of 1020 kg/ha and total production of 55.06 lakh ton during the year of 2016–17 (Anonymous, 2018). The south and central India particularly the state of Madhya Pradesh and Maharashtra are the hubs of soybean production in India, where soybean has already been established as an important industrial crop. In recent year, soybean production and the area coverage under cultivation has declined due to regular occurring of abiotic and biotic stresses. Among biotic factors, pest and diseases are the most important ones for low productivity. Frogeye leaf spot (FLS) of soybean caused by *Cercospora sojina* Hara, is a very severe disease in the warm and humid tropical and subtropical regions of the world (Phillips 1999; Das et al. 2017) and the incidence of FLS is dependent on the growing conditions (Akem and Dashiell 1994). Frogeye leaf spot is primarily a disease of foliage even though stems, pods and seeds may also be infected (Phillips 1999). The seedlings from infected seeds may have lesions on the cotyledons (Sherwin and Kreitlow 1952) but the lesions on leaves do not appear for nearly 7–14 days after invasion of the host tissues, so they are not visually observed on young expanding leaves. Soybean yield reductions of 10–60% due to FLS have been reported (Mittal 2001; Mian et al. 1998). These decreases in yield are a result of reduced photosynthetic area, premature defoliation (Akem and Dashiell 1994) and reduced seed

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size. Since it is a fungal disease, its control through chemical practice is not effective, nor is it environment friendly. FLS may be partially managed by planting disease-free seed, treatment of seed with a fungicide before planting, crop rotation, treatment of R2 to R5 growth stage soybean foliage with fungicides, and planting resistant cultivars if available (Mian et al. 2009). Various fungicides control the disease with dissimilar cost–benefit ratio (Das 2015). Deployment of genetic resistance is the best approach for management of FLS disease. Identification and incorporation of resistance in high yielding genotypes is the best way to minimize the losses caused by disease. In view of the increasing incidences of this disease in recent past, an attempt was made in the field trial to know the resistance level of different genotypes under high disease pressure/ hot spot condition to identify highly resistant genotypes. However, incorporating this resistance from identified genotypes and making genetic resistance to be effective, it is important to understand the genetic control of the disease resistance. The resistance of genotypes may vary from region to region depending upon the strain of fungus prevalent in the area. The present study was designed to evaluate soybean genotypes at Experimental Farm, Hawalbagh, ICAR-VPKAS, Almora, which is considered as hot spot location for FLS to identify sources of resistance to Frogeye leaf spot disease of soybean.

Field screening for Frogeye leaf spot (FLS) disease resistance in soybean genotypes were carried out at Experimental Farm, ICAR–VPKAS, Hawalbagh ($29^0$56′N, $79^0$40′E, 1250 m MSL) during the *kharif* season in the year 2018 and 2019. This material was received through AICRP Soybean and Hawalbagh centre is recognized as a hot spot for frog eye leaf spot disease since the disease appears in severe to moderate epiphytotic form under natural climatic conditions. Forty five different soybean genotypes along with two highly susceptible check varieties Shivalik and Bragg were screened to find out the resistance level of the lines. Each of the genotypes was sown in a plot of three rows of 03 m length following Randomized Block Design during second fortnight of June month. One row of susceptible check was repeated after every five entries. All the recommended agronomic practices were followed to grow a healthy crop. Uniform method of disease rating was followed. Data obtained in the field experiments were analysed using two-factorial randomized block design (RBD) and were transformed to angular scale to stabilize the variance. Critical differences were calculated at the 5% probability level of significance for comparison of genotype means and per cent disease index. Point scale (0 to 9) divided into 6 categories was adopted, where, 0 = No lesions/spots; 1 = 1% leaf area covered with lesions/spots; 3 = 1.1–10% leaf area covered with lesions/spots, no spots on stem; 5 = 10.1–25% of the leaf area covered, no defoliation, little damage; 7 = 25.1–50% leaf area covered; some leaves drop, death of a few plants, damage conspicuous; 9 = More than 50% area covered, lesions/spot very common on all plants, defoliation common, death of plants common, damage more than 50%. The high incidence of FLS in Bragg and Shivalik, the two susceptible checks, ensured the high incidence of FLS and better reliability of the resistance.

Disease incidence was recorded and Percentage Disease Index (Anonymous 2019) was worked out using the formula,

PDI = [Sum of numerical rating /total number of leaves examined x maximum disease score] × 100. On the basis of PDI, the genotypes were classified as follows:

PDI	Categories
0.0	Absolutely resistant/ Immune (AR/I)
0.01–11.11	Highly resistant (HR)
11.12–33.33	Moderately resistant (MR)
33.34–55.55	Moderately susceptible (MS)
55.56–77.77	Susceptible (S)
77.78–100.00	Highly susceptible (HS)

Resistant varieties are considered as the most durable option for management of frog eye leaf spot disease in soybean (Das et al. 2017). All the genotypes were critically observed for the entire crop period. The symptoms of frog eye leaf spot have started appearing in first fortnight of August and maximum disease severity was noticed during the month of September. Per cent Disease Index varied from 1.9% to 78.8%. None of the genotypes was found Immune (PDI 0%). Eleven genotypes *i.e.* NRC 88, VS 2004–9, VS 2005–40, VS 2006–17, DSB 11, NRC 84, AMS-MB-5–19, VLS 86, Himso 1685, MACS 1407, and MACS 1442 were found to be highly resistant (PDI 1.9%–10.9%) with VS 2005–40 and MACS 1442 showed minimum and maximum PDI, respectively (Table 1). Twenty seven genotypes *i.e.* JS 20–34, VLS 76, KDS 344, VLS 47, JS (SH)2002–14, NRC 79, AMS 1, NRC 82, JS 20–19, VLS 74, VLS 73, DSB 20, AMS-MB-5-18, KDS 378, NRC 99, VLS 89, KDS 753, KDS 869, VLS 92, MACS 1575, NRC 129, Salimar, DSb 21, JS 20-116, KDS 980, KDS 1045 and BAUS 96 showed moderately resistant reaction (PDI 11.3% to 28.8%) and seven genotypes *i.e.* VLS 87, TS 53, SL 1123, RVS 2011–2, JS 75–46, NSO 81, NRC 85 showed moderately susceptible reaction (PDI 33.5% to 50.7%). Only Bragg showed susceptible reaction (72.1% PDI) and Shivalik was found highly susceptible (78.8% PDI) (Table 1).

It was noticed that the proportion of resistant genotypes was relatively high in comparison to susceptible amongst all the tested genotypes. Out of 45 genotypes screened,

Table 1 Reaction of genotypes against Frog eye leaf spot disease

S. No	Variety/ Genotype	Pedigree	PDI (2018)	PDI (2019)	Pooled PDI	Disease Reaction
1	JS 20–34	JS 98–63 × PK768	12.2 (20.4)	11.1 (19.5)	11.6 (19.9)	MR
2	VLS 76	Hardee × JS 335	11.2 (19.4)	23.3 (28.8)	17.2 (24.2)	MR
3	KDS 344	JS 335 × EC 241,780	11.1 (19.4)	11.6 (19.9)	11.3 (19.7)	MR
4	NRC 88	MAUS 61–2 × NRC 7	0.6 (3.0)	12.2 (20.4)	6.3 (11.7)	HR
5	VS 2004–9	EC 361,362 × Hardee	11.6 (19.9)	3.8 (11.3)	7.7 (15.6)	HR
6	VS 2005–40	Pusa 16 × Hardee	1.1 (4.2)	2.7 (9.5)	1.9 (6.8)	HR
7	VS 2006–17	PRS 8901 × PK 564	0.6 (3.0)	11.1 (19.5)	5.8 (11.2)	HR
8	VLS 47	Selection from KHSF-3	11.2 (19.4)	16.1 (23.4)	13.6(21.4)	MR
9	DSB-11	PK 472 × DSb-5	11.1 (19.4)	10.5 (18.9)	10.8 (19.2)	HR
10	JS (SH)2002–14	DSb x NSP 7	20.6 (27.0)	24.4 (29.6)	22.5 (28.3)	MR
11	NRC 79	PK 416 × NRC 55	11.1 (19.4)	22.2 (28.1)	16.6 (23.8)	MR
12	AMS 1	Selection from Bragg	11.1 (19.4)	13.4 (21.4)	12.2 (20.4)	MR
13	NRC 82	NRC2 x Palam Soya	10.5 (18.8)	22.2 (28.1)	16.3 (23.5)	MR
14	JS 20–19	MACS 330 × L 129	10.6 (18.9)	13.3 (21.3)	11.9 (20.2)	MR
15	NRC 84	PK 416 × NRC 55	11.1 (19.4)	10.5 (18.9)	10.8 (19.2)	HR
16	VLS 74	Hardee × JS 335	31.8 (34.3)	22.7 (28.5)	27.2 (31.4)	MR
17	VLS 73	PRS 8901 × PK 564	10.7 (19.1)	30.8 (33.7)	20.7 (26.4)	MR
18	DSB 20	JS 335 × EC 24,778	13.3 (21.4)	11.6 (19.9)	12.5 (20.6)	MR
19	AMS-MB-5–18	Mutant of Bragg	31.9 (34.4)	22.4 (28.2)	27.1 (31.3)	MR
20	AMS-MB-5–19	Mutant of Bragg	10.7 (19.1)	10.5 (18.9)	10.6 (19.0)	HR
21	KDS 378	JS 335 × EC241780	31.8 (34.3)	10.6 (18.9)	21.2 (26.6)	MR
22	VLS 86	VLS 47 × EC 361,360	10.7 (19.1)	10.6 (18.9)	10.6 (19.03)	HR
23	VLS 87	VHC 3022 × EC 361,360	54.9 (47.8)	12.2 (20.4)	33.5 (34.1)	MS
24	Himso 1685	H 330 × Hardee	0.5 (3.0)	4.9 (12.8)	2.7 (7.9)	HR
25	MACS 1407	MAUS 144 × MACS 450	0.5 (2.9)	5.0 (12.7)	2.7 (7.8)	HR
26	NRC 99	EC546882 × PS1024	11.1 (19.4)	11.6 (19.9)	11.3 (19.6)	MR
27	VLS 89	VLS47 x EC 361,364	10.8 (19.2)	33.8(35.5)	22.3 (27.3)	MR
28	KDS 753	JS 93–05 × EC 241,780	11.1 (19.4)	13.3 (21.3)	12.2 (20.3)	MR
29	KDS 869	JS335 × EC 538,800	16.1 (23.3)	11.1 (19.4)	13.6 (21.4)	MR
30	MACS 1442	MACS 1037 × JS 335	10.6 (19.0)	11.2 (19.5)	10.9 (19.2)	HR
31	VLS 92	VLS74 × JS 95–60	22.7 (28.4)	22.7 (28.4)	22.7 (28.4)	MR
32	TS 53	Punjab1 × EC34160	34.9 (36.2)	56.0 (48.4)	45.5 (42.3)	MS
33	SL 1123	Selection from AGS751	34.3 (35.8)	67.1 (55.0)	50.7 (45.4)	MS
34	MACS 1575	PI542044 × JS 93–05	11.6 (19.9)	42.4 (40.6)	27.0 (30.2)	MR
35	NRC 129	EC538828 × NRC7	23.3 (28.8)	34.3 (35.8)	28.8 (32.3)	MR
36	RVS 2011–2	JS20-63 × JS95-60	33.3 (35.2)	56.0 (48.4)	44.6 (41.8)	MS
37	Salimar	Selection from local landrace AGR/538 (n)	11.1 (19.4)	32.7 (34.8)	21.9 (27.1)	MR
38	DSb 21	JS335 × EC241778	13.8 (21.7)	23.8 (29.2)	18.8 (25.4)	MR
39	JS 75–46	Improved Pelican × Semmes	26.5 (30.9)	44.9 (42.1)	35.7 (36.5)	MS
40	JS 20–116	JS 97–52 × JSM 120A	10.6 (18.9)	33.9 (35.5)	22.2 (27.2)	MR
41	KDS 980	JS93-05 × AMS1	27.0 (31.2)	11.6 (19.9)	19.3 (25.6)	MR
42	KDS 1045	JS90-60 × EC241780	12.2 (20.4)	11.6 (19.9)	11.9 (20.1)	MR
43	NSO 81	JS 11–05 × JS 335	27.0 (31.2)	56.0 (48.4)	41.5 (39.8)	MS
44	NRC 85	JS93-05 × EC 394,837	33.3 (35.2)	43.8 (41.3)	38.5 (38.2)	MS
45	BAUS 96	Monetta × EC34500	10.6 (18.9)	23.3 (28.8)	16.9 (23.9)	MR
46	Shivalik (Susceptible check)	Selection from segregating PK 73–55	78.2 (62.1)	79.3 (62.9)	78.8 (62.5)	HS

Table 1 (continued)

S. No	Variety/ Genotype	Pedigree	PDI (2018)	PDI (2019)	Pooled PDI	Disease Reaction
47	Bragg (Susceptible check)	Jackson x D49-2491	76.1 (60.6)	68.2 (55.6)	72.1 (58.2)	S

Factors	C.D	SE(d)	SE (m)
A (Genotype)	3.21	1.62	1.14
B (PDI)	0.66	0.33	0.24
AxB (Interaction)	4.54	2.28	1.62

*Fig. in parentheses are angular transformed values

none was Immune, 24.44% were highly resistant, 64.44% were moderately resistant, and 15.55% were moderately susceptible to FLS disease. Several workers have reported different level of resistance against frogeye leaf spot disease in soybean. The results obtained were in accordance with the findings of Khati et al. (2007); Chandra et al. (1995); Das et al. (2017); Amrate et al. (2018, 2020). Das et al. (2017) while screening of soybean varieties for resistance to frogeye leaf spot disease found no immune variety (disease severity 0%). However, fifteen varieties *i.e.*, RKS 18, PK 564, PS 1241, PK 1092, Indira Soya 9, PS 1029, NRC 37, PS 1347, MAUS 71, PK 1024, PK 472,PK 416, Alankar, Ankur, JS 335 were observed to be resistant (disease severity 1%–10%); eight varieties (NRC 37, PS 19, PK 327, RAUS 5, PK 1042, JS 9752, Shilajeet, JS -20-29) were moderately resistant (disease severity 10%–20%) and two varieties (Kalitur and Bragg) showed moderately susceptible reaction (disease severity 20%–30%). Only one variety *i.e.*, PK 262 was found susceptible (disease severity 30%–50%) and none was found highly susceptible (disease severity above 50.1%). Since the resistance amongst the selected genotypes have been confirmed over 2 years under high disease pressure, therefore, these resistant and moderately resistant genotypes may be used as source of donors for evolving resistant varieties against Frogeye leaf spot disease in future breeding programme.

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