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Host plant resistance and epidemiology of sterility mosaic virus disease in pigeonpea (*Cajanus cajan* (L.) Millsp.)

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ABSTRACT

Field experiments were conducted to identify the resistant sources for Sterility Mosaic Disease (SMD) in pigeonpea at the experimental farm, Department of Pulses,Centre for Plant Breeding and Genetics, Tamil Nadu Agricultural University,Coimbatore. Out of 25 genotypes screened under field condition by infector row technique, three entries *viz*., BDN 2, IPA 8F and MA6 showed resistant reaction to SMD consistently for three years with the mean disease incidence of 8.3, 6.9 and 8.7 % respectively. Seven genotypes viz., BRG1, BRG3, BSMR 736, ICP 7035, ICP 2376, IPA 15F and KPL 44 were categorized as moderately resistant genotypes with the disease incidence ranging from 14.8 - 19.2 %. Six genotypes exhibited moderately susceptible reaction, seven genotypes were susceptible and the remaining two genotypes were highly susceptible to the disease. The susceptible checks *viz*., CO5 and ICP8863 recorded the SMD incidence of 85.3 and 93.6 % respectively. All the 25 pigeonpea genotypes were also evaluated under glass house for their reaction against SMD by leaf stapler technique. The genotypes, *viz*., BDN 2, IPA 8F and MA6 also exhibited resistance to SMD under artificial inoculation condition, whereas the susceptible checks *viz*., CO5 and ICP 8863 recorded 100 % SMD incidence. Wide variations were found between resistant and susceptible pigeonpea genotypes for SMD symptom expressions. The resistant genotypes would be of great value for development of pigeonpea cultivars with SMD resistance. In the present study, results of the experiment on epidemiology of SMD indicated that SMD incidence and mite population were negatively correlated with temperature and positively correlated with relative humidity. The average temperature of 29 - 29.2° C and the RH of 89 - 92.5 % was found to favour the SMD incidence in pigeonpea. The results from this study would be helpful to take timely decision for management of SMD.

***Key words*:** Epidemiology, Genotype screening, Pigeonpea, Resistance, SMD

INTRODUCTION

Pigeonpea (*Cajanus cajan* (L.) Millsp.), also known as redgram or arhar, is the fifth prominent pulse crop in the world and the second most important pulse crop in India. It is one of the high value and low input requiring drought tolerant pulse crops that offers many benefits to farmers as food, fodder, feed and fuel. It is widely grown in Tamil Nadu as a rainfed crop. Globally, pigeonpea cultivation is spread over an area of 7.02 m ha with an average production and productivity of 6.81 m tonnes and 970 kg ha^{-1} respectively (FAOSTAT, 2017). In India it is grown in an area of 4.78 m ha with the production of 3.59 m tonnes and productivity of 751 kg ha^{-1} (DES 2018). India stands first in the area and production of pigeonpea in the globe but its productivity lower than world average (FAOSTAT, 2013). The biotic and abiotic factors encountered by crop at different stages of growth are majorly responsible for this yield gap in India. Among biotic factors, Sterility Mosaic Disease (SMD) incited by Pigeonpea Sterility Mosaic Virus (PPSMV) is an important constraint which is found to occur in almost all pigeonpea growing regions. The infected plants show bushy and pale green appearance with small leaf, excessive branches, partial or complete sterility, sometimes part of the plants show symptoms other parts remain normal (Kumar *et al.,*2003).The disease is transmitted through an Eriopphid mite (*Aceria cajani* Channabasavanna) in a semi persistent manner (Kulkarni *et al.*2002; Jones *et al.,* 2004).

The yield loss caused by SMD was estimated up to 95 % and it depends on growth stage of the plant at which infection occurred (Kannaiyan *et al*. 1984; Ganapathy *et al.,* 2011). Early stage of infection resulted in 90 % yield loss in pigeonpea (Bhaskaran and Muthiah, 2005). Management of SMD through

acaricides is not much effective and economic, moreover it causes environmental pollution. Exploiting host plant resistance is the most viable and economic strategy for SMD management. Developing resistant varieties in pigeonpea is a difficult task because of genetic plasticity of PPSMV whose virulence depends on location-specific environments (Sharma *et al*. 2012b). Reddy *et al.* (1993) reported existence of five different isolates of PPSMV in India. The variation in SMD symptom expression have been observed among various pigeonpea genotypes and it differs based on time of infection (Ghanekar,1992; Reddy *et al*.,1993). Though SMD is widely prevalent in most of pigeonpea growing regions, its incidence varies seasonally and also from one region to another (Kumar *et al*., 2008). Progress of development of SMD depends on proximity to source of inoculum, plant age, pigeonpea cultivar, climatic factors and mite population (Teifion Jones *et al*., 2004). In India, limited research work has been done on epidemiology of SMD. Many workers identified resistance sources against SMD across the world but host resistance in disease management is seriously curtailed as a result of genetic breakdown or change in virulence of pathogen, making it imperative to continuously search for resistant sources. Therefore, the present investigation was carried out with the objective of identifying resistant sources for SMD and to ascertain the influence of .climatic factors *viz*., temperature, RH and wind velocity on SMD incidence.

MATERIALS AND METHODS

Evaluation of pigeonpea genotypes for SMD resistance

Experimental site and source of seeds

Field experiments were conducted at the Research farm, Department of Pulses, Centre for Plant Breeding and Genetics, Tamil Nadu Agricultural University, Coimbatore (11.0168°N, 76.9558°E) consecutively for the three years during 2015 - 2018, *kharif* season to identify the resistant sources for SMD. The experimental material comprising of 25 genotypes and susceptible check ICP 8863 was obtained every year from AICRP pigeonpea coordinating centers. Seeds of local check variety *viz*., CO5 was collected from the Department of Pulses, TNAU, Coimbatore. The ten genotypes used for studying the symptom variability was also received from pigeonpea AICRP coordinating centers.

Field Experiments (Infector row technique)

The seeds of 25 test genotypes were sown during the first week of August in 4 m row with spacing of 75 cm and plant to plant to plant spacing of 20 cm. Two replications were maintained for each genotype. The local susceptible check CO5 was raised in between 4 rows of test genotypes. The National susceptible check ICP 8863 was sown along border lines of test rows to increase disease pressure. The crop was maintained by following standard agronomic practices as per the recommendation of the TNAU crop production guide without spraying any insecticides or fungicides. The observations recorded on SMD incidence on 30, 60, 90, 120 and 150 days after sowing and the percent disease incidence were calculated using the formula

$$\% \text{ SMD incidence} = \frac{\text{Number of plants infected}}{\text{Total number of plants observed}} \times 100$$

Based on the % disease incidence the genotypes were categorized for SMD resistance by adopting disease score developed by Pande *et al.* (2012) with slight modifications

SMD incidence %	Disease reaction
0 – 10	Resistant
10.1 – 20	Moderately resistant
20.1- 30	Moderately Susceptible
30.1- 50	Susceptible
50.1 – 100	Highly Susceptible

Glass house Evaluation (Leaf stapler technique)

All the 25 genotypes evaluated under field were also tested under glass house for their resistance against SMD under glass house by leaf stapler technique. The seeds of test genotypes were sown in 30 cm pots containing mixture of red soil + sand + FYM (2:1:1) @ five seeds/ pot. Each genotypes four replications were maintained. The inoculum source *viz.*, SMD infected leaflets were collected from the ICP 8863 which was maintained at the PL480 glass house, Department of Plant Pathology, Centre for Plant Protection Studies, Tamil Nadu Agricultural University, Coimbatore. The leaflets were observed under the Binocular microscope for the presence of Eriophyid mite (*A. cajani*). The infected leaf lets with mite was stapled on the 10 - 12 days old seedlings of each test genotype in such a way that the lower surface of the leaflets were in contact with the both the leaf surface of the seedling. The variety CO5 and the ICP 8863 were used as the susceptible checks. The observation on SMD incidence was recorded on 30, 45 and 60 days after sowing and the reaction of the genotypes against SMD was determined as per the disease score described above.

Influence of climatic factors on mite population and SMD incidence:

The influence of weather factors *viz*., temperature, relative humidity (RH) and wind velocity on SMD

incidence and mite population was determined by conducting field experiments consecutively for three years from 2015-16, 2016-17 and 2017-18 using susceptible check ICP 8863. Every year, early, normal and delayed sowing was taken during the third week of July, first week of August and third week of August respectively. For each sowing, 30 rows of 4 m length with plant to plant spacing of 20 cm were maintained. The plants were maintained by adopting standard package of practices without taking any plant protection measures. The observations recorded on SMD incidence at 15 days intervals starting from second week of September to second week of January. The meteorological observations *viz*., temperature, RH and wind velocity were obtained from the Agro climate Research Centre, Tamil Nadu Agricultural University, Coimbatore. The % disease incidence for SMD was worked out. The Area Under Disease Progress Curve (AUDPC) was calculated as described by Campbell and Madden (1990) and the Rate of spread of disease per day(r) was worked out as per the formula furnished below. The correlation between weather parameters *viz*., temperature, RH and wind velocity and SMD incidence was determined.

$$\text{AUDPC} = \sum_{i-1}^{n-1} \left[\frac{X(i+1) + (Xi)}{2} \right] x \left[t(i+1) - t\,i \right]$$

Where Xi = intensity of disease at i^{th} observation

t_i = time interval

$$\text{Rate of spread of disease(r)} = \frac{X_2 - X_1}{t_2 - t_1}$$

X_2 = disease proportion at time t_2

$t_2 - t_1$ = time interval

The mite population was recorded at 15 days intervals starting from second week of September to second week of January. Five plants were selected and from each plant three trifoliate leaves were collected and the mite population count was directly recorded under stereo- binocular microscope. It was expressed as number of mites per trifoliate leaf.

RESULTS AND DISCUSSION

Reaction of pigeonpea genotypes against SMD

A total of 25 pigeonpea genotypes were evaluated in the field for SMD resistance by infector row technique for three years from 2015 to 2018 and these genotypes revealed varying response against SMD. Amongst these, three genotypes *viz*., BDN 2, IPA 8F and MA6 exhibited resistant reaction to SMD across three years that recorded the mean SMD incidence of 8.3, 6.9 and 8.7 % respectively. SMD incidence in seven genotypes *viz*., BRG 1, BRG 3, BSMR 736, ICP 7035, ICP2376, IPA 15F and KPL 44 ranged between 14.8 - 19.2 % and were grouped as moderately resistant. Six pigeonpea genotypes *viz*., BRG 2, BRG 4, CRG9701, ICP 7119, KPL 43, MAL 13 with the SMD incidence of 24.2 – 29.2 were categorized as moderately susceptible. Seven entries showed susceptible reaction and the two genotypes *viz*., MAL 43 and RVSA 07-31 were highly susceptible to SMD. The susceptible checks *viz*., CO 5 and ICP8863 registered a mean SMD incidence of 85.3 and 93.6 % respectively (Tables 1 and 2). Earlier, several workers identified resistant sources for PSMD. Shiv *et al*. (2008) reported that out of 22 pigeonpea genotypes, TT 701 was completely free from SMD infection. Sharma *et al*. (2015) carried out multi-environment screening and identified broad based stable resistant sources *viz*., ICPL 20094, ICPL 20106, ICPL 20098 and ICPL 20115 against SMD. Out of 60

Table 1. Reaction of pigeonpea genotypes against SMD under field condition (Infector row technique)

S. No.	Pigeonpea genotypes	SMD incidence (%)* 2015-16	2016-17	2017-18	Mean Incidence (%)
1	**BDN 2**	**9.5**	**9.2**	**6.3**	**8.3**
2	BRG 1	23.4	17.7	18.4	19.8
3	BRG 2	19.9	20.7	32.1	24.2
4	BRG 3	15.5	15.0	17.8	16.1
5	BRG 4	34.5	22.5	30.5	29.2
6	BSMR 736	17.4	19.6	19.1	18.7
7	BSMR 853	45.0	42.6	40.5	42.7
8	CO 6	43.5	41.0	38.5	41.0
9	CRG 9701	30.5	28.4	25.7	28.2
10	ICP 7119	31.7	28.4	27.1	29.0
11	ICP 7035	17.5	14.4	12.5	14.8
12	ICP 2376	18.7	20.0	15.9	18.2
13	**IPA 8F**	**7.7**	**6.9**	**6.3**	**6.9**
14	IPA 15 F	24.4	18.2	15.5	19.3
15	JKM 189	41.7	44.2	59.7	48.5
16	KPL 43	24.1	25.5	27.9	26.0
17	KPL 44	20.0	19.3	18.4	19.2
18	MAL 13	21.4	27.4	29.7	26.2
19	MA 6	**9.6**	**9.3**	**7.1**	**8.7**
20	MAL 43	68.7	58.4	59.2	62.1
21	RVSA 07-31	54.6	51.7	48.6	51.6
22	RVSA 07-29	55.8	48.1	45.9	49.3
23	RVSA 07-10	52.5	47.0	48.6	49.3
24	WRGE 65	60.0	55.0	18.4	44.4
25	WRP 1	51.9	40.5	45.	45.8
26	CO 5	87.5	90.3	100	85.3
27	ICP 8863	90.7	92.5	100	93.6

*Mean of two replications

Table 2. Grouping of pigeonpea genotypes based on their reaction against SMD in the field

Pigeonpea genotypes	No. of genotypes	Disease incidence (%)	Disease reaction
BDN 2, IPA 8F ,MA6	3	6.9 - 8.7	Resistant
BRG 1, BRG 3, BSMR 736,ICP 7035 ICP2376, IPA 15F, KPL 44	7	14.8 - 19.2	Moderately resistant
BRG 2, BRG 4, CRG9701, ICP 7119, KPL 43, MAL 13	6	24.2 – 29.2	Moderately Susceptible
BSMR 853, CO6, JKM 189, , RVSA 07-10, RVSA 07-29 WRP 1,WRGE 65	7	41- 49.3	Susceptible
MAL 43 , RVSA 07-31	2	51.6 - 62.1	Highly Susceptible
Local Susceptible Check Co5	1	85.3	Highly Susceptible
National Susceptible Check ICP 8863	1	93.6	Highly Susceptible

pigeonpea genotypes evaluated for SMD resistance eight entries viz., ICPL-87119, ICPL-2376, BDN-2, PT-4-307, CORG-9701, BSMR-736, GRG-811 and BSMR-853 were resistant to SMD (Vijaya Bhaskar, 2016). Prabhavathi and Ramappa (2018) reported that only one entry *viz*., RKPV 405-10 showed resistant reaction to SMD among the 13 genotypes and the remaining were susceptible with 68 to 100 %.

The reaction of all the 25 genotypes against SMD were tested under glass house condition by adopting leaf stapler technique along with susceptible checks CO5 and ICP 8863 .The genotypes *viz*., BDN2, IPA 8F and MA6 were found to be resistant in the artificially inoculated condition also. Four genotypes viz., BRG 3, ICP 7035, ICP2376 and KPL 44 were grouped under moderately resistant category which recorded SMD incidence ranged from 19.3 to 20.0 % (Fig 1**).** Eight genotypes showed moderately resistant reaction, the susceptible checks *viz*., CO5 and ICP8863 recorded 100 % SMD incidence (Fig 2). Manjunatha *et al.*(2013) found that the genotypes *viz*., ICP 7035, BRG3, ICPL87091, GT101 and JKM189 were found to be resistant to SMD. Tharageshwari *et al.*(2019) evaluated 94 genotypes under glass house by leaf stapler technique and found four genotypes *viz*., DPP 2-89, DPP 3-182, IC 22557 and ICP 3666 were resistant to SMD.

Variability in symptom expression for SMD in resistant and susceptible genotypes

The SMD symptoms expressed by the resistant, moderately resistant, moderately susceptible, susceptible and highly susceptible genotypes were studied under field condition by adopting infector row technique. From this study, wide variation was observed between these genotypes for SMD expression. The resistant genotypes *viz*., IPA 8F showed only ring spot and upward cupping of leaves and the moderately resistant genotypes *viz*., BRG1 and BRG3 expressed symptoms *viz*., ring spot, mild chlorosis, stunting and partial sterility. The moderately susceptible and genotypes exhibited all symptoms of SMD except few symptoms while in highly susceptible genotypes *viz*., CO5 and ICP 8863 all the characteristic symptoms of SMD including complete sterility were observed(Table 3). This was in concordance with findings of Ghanekar (1992) who reported that SMD symptom expression in pigeonpea depends on type of genotype. Ssymptoms of SMD varied with location (Reddy *et al*., 1998) and its incidence differed from plant

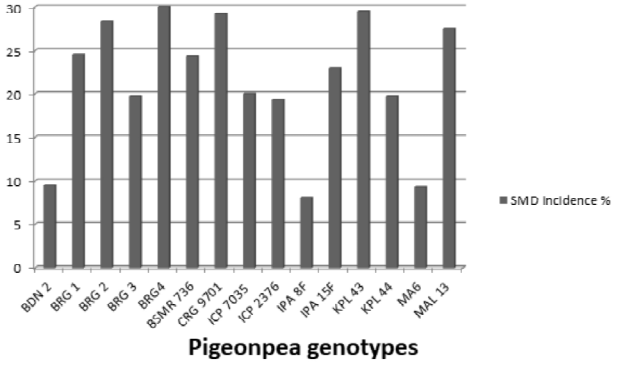

Fig. 1. Incidence of SMD in resistant, moderately resistant and moderately susceptible genotypes identified in glass house evaluation

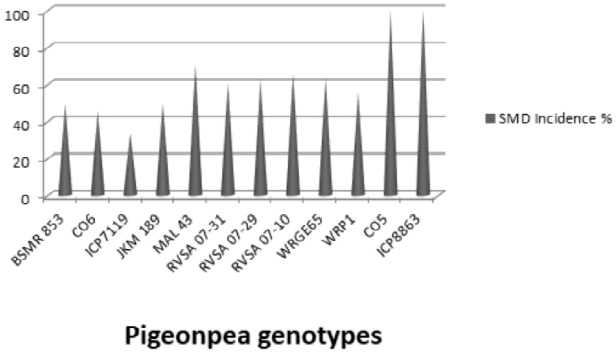

Fig. 2. Incidence of SMD incidence in susceptible and highly susceptible genotypes identified in glass house evaluation

to plant due existence of variability in the pathogen (Kulkarni *et al*., 2003). In SMD resistant varieties, flowering and pod formation was normal while in susceptible variety complete cessation of reproductive parts occurred due to severe mosaic symptoms (Kaushik *et al*., 2013). The variable symptoms expressed by the resistant and susceptible genotypes helped to identify the SMD resistant sources easily.

Epidemiology of SMD

Epidemiological studies revealed that SMD appeared during second week of September in early sown crop (3rd week of July) and gradually reached 100 % incidence during second week of December. However, in the normal sown crop (1st week of August) and delayed sown crop (3rd week of August) crop also 100 % SMD incidence was observed during December second week. The Area Under Disease Progress Curve (AUDPC) showed an increase from initial incidence to later stages of infection and reached to 1466.4, 1432.5 and 1301.3 during the second week of December in early, normal and delayed sowing respectively. The maximum AUDPC of 1500 was recorded in all the three sowing during the fourth week of December (Table 4). The rate of spread of disease per day was the highest (1.3) during the November fourth week in the early sown crop and in normal sown crop the spread was more (1.7) during the second week of October and in late in crop it was high (1.8) during fourth week of October. Ranjit Kumar Paul *et al* (2018) studied

Table 3. Differential symptoms of SMD expressed by various pigeonpea genotypes

S. No	Nature of symptoms	Genotypes									
		CO 5	CO6	CO(Rg) 7	Bahar	BRG 1	BRG 3	SMR 736	IPA 8F	ICP 8863	Purple
1.	Rings pot	+	+	+	+	+	+	+	+	+	-
2.	Mild chlorosis	-	-	-	+	+	+	-	-	-	+
3.	Severe chlorosis	+	+	+	-	-	-	+	-	+	-
4.	Malformation of leaves	+	+	+	-	-	-	-	-	+	-
5.	Puckering of leaves	+	-	-	-	-	-	-	-	+	-
6.	Upward cupping of leaves	-	-	-	+	-	-	-	+	-	-
7.	Reduction in leaf size	+	+	+	-	-	-	-	-	+	+
8.	Bushy appearance of the plants	+	+	+	-	-	-	-	-	+	-
9.	Stunting of plants	+	-	+	-	+	+	-	-	+	+
10.	Partial sterility	+	-	+	-	+	+	-	-	+	
11.	Complete sterility	+	+	+	-	-	-	-	-	+	-
12	Disease reaction	HS	S	MS	MR	MR	MR	MR	R	HS	R

+ Present, - Absent, HS - Highly Susceptible, S - Susceptible, MS - Moderately Susceptible, MR - Moderately Resistant, R - Resistant

Table 4. SMD incidence and mite population in pigeonpea and environmental variables

Time of Observation	Earlier sowing (IIIrd of week of July)*				Normal sowing Ist week of August*				Delayed sowing IIIrd week of August*				Temperature oC*	RH %*	Wind velocity Km/ h*
	Incidence (%)	AUDPC	Rate of spread/ day	Mite population	Incidence (%)	AUDPC	Rate of spread/ day	Mite population	Incidence (%)	AUDPC	Rate of spread/ day	Mite population			
September IInd week	11	-	-	1.5	0	-	-	-	0	-	-	-	32.5	76	6.1
September IVthweek	26	277.5	1.0	3.7	5	37.5	0.3	4.8	0	0	-	-	32.3	90.5	5.1
October IInd week	45	532.5	1.2	15.4	31	270	1.7	17.7	8.5	63.8	0.5	7.2	31.75	85	5.7
October IVthweek	60.5	791.3	1.0	27.3	49.5	603.7	1.2	30.5	36.5	337.5	1.8	25.5	31.9	88.5	4.2
November IInd week	76	1023.7	1.0	31.5	66.5	870.0	1.1	35.7	48.5	637.5	0.8	30.7	30.0	94.5	3.3
November IVthweek	95.5	1286.3	1.3	40.2	91	1181.3	1.6	42.4	73.5	915	1.6	39.1	29.2	92.5	4.9
December IInd week	100	1466.4	0.3	43.7	100	1432.5	0.6	46.7	100	1301.3	1.7	42.6	29.0	90.0	5.8
December IVthweek	100	1500	0	45.5	100	1500	0	52.3	100	1500	0	50.4	29.5	89.0	5.9
January IInd week	100	1500	0	40.5	100	1500	0	50.5	100	1500	0	45.2	29.3	87.0	5.3

*Mean of three years data (2015- 16, 2016- 17 and 2017 – 18)

Table 5. Correlation between SMD incidence, mite population and environmental variables

Details of sowing	SMD incidence %			Mite population		
	Temperature °C	RH %	Wind velocity Km/h	Temperature °C	RH %	Wind velocity Km/h
Early sowing (3rd of week of July)	- 0.953	0.600	- 0.132	- 0.932	0.562	- 0.1176
Normal sowing (1st week of August)	- 0 .956	0.530	- 0.0746	- 0.922	0.552	- 0.122
Delayed sowing (3 rd week of August)	- 0.933	0.426	0.047	- 0.925	0.509	- 0.091

incidence of SMD during *kharif* seasons of 2012-15 and found that the infection occurred during second week of August with peak incidence during third week of October to November.

In the early sown crop the mite population of 1.5 was recorded during the initial crop growth period and it was increased and reached the maximum of 45.5 during the fourth week of September. In the normal and delayed sown crop also the mite population showed an increasing trend from early crop growth to later stage. The highest population of 52.3 and 50.4 was observed in early and late sown crop respectively during the fourth week of December. Pallavi *et al.*(2021) recorded the lowest disease incidence and mite population during the early crop growth period which gradually increased at later stage of crop growth period. The results of the present investigation revealed that, the period between the fourth week of November to second week of December was found to be favorable for SMD incidence and the multiplication of mites. During this period the temperature of 29 to 29.2 °C and RH of 89 - 92. 5 % and the wind velocity of 4.8 – 5.9 km / h were recorded. Pallavi *et al.* (2021) found that the maximum temperature of 27.6 to 38.9°C and RH of 82.4 to 91.3% coupled with scanty rains prevailing during April-June at Bangalore favoured the rapid multiplication of the vector leading to higher disease incidence.

The results of the correlation analysis showed that the SMD incidence and mite population were strong negative correlation with temperature (Table 5). The present finding is in corroboration with the results reported by Reddy and Raju (1993) and Ranjit Kumar Paul *et al* (2018). Kausik *et al* (2013) found that very high temperature is not suitable for mites and the average temperature of 20-30°C was found to be congenial for the multiplication of mite. In this study, the positive correlation was found between SMD incidence and RH. Pallavi *et al* (2021) observed positive influence of morning RH on SMD during June, July, while Ranjit Kumar Paul *et al*. (2018) reported negative correlation of evening RH with SMD. Increased mite population resulted in increased SMD severity (Lakshmikantha and Prabhuswamy, 2002). In the present investigation insignificant correlation was observed between wind velocity and SMD incidence. Reddy *et al*. (1990) reported that SMD can spread up to 2 km downwind from the source of inoculum but the spread in an up-wind direction was very limited (less than 200 m) confirming that wind assist in mite dispersal.

CONCLUSION

The genotypes *viz.*, BDN2, IPA8F and MA6 showing resistance to SMD both under field and glass house conditions. The identified genotypes from this study will be exploited in breeding programme for developing elite pigeonpea cultivar with SMD resistance. In future, detailed epidemiological studies on SMD will be helpful for developing forecasting model to give forewarning to the farmers to take protection measures against the disease.

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