Int.J.Curr.Microbiol.App.Sci (2024) *13*(11): 228-242

International Journal of Current Microbiology and Applied Sciences
***ISSN: 2319-7706* Volume 13 Number 11 (2024)**
Journal homepage: http://www.ijcmas.com

Original Research Article https://doi.org/10.20546/ijcmas.2024.1311.026

Studies on Prevalence and Morphological Symptom Characterisation of Pigeonpea Sterility Mosaic Virus Isolates from Major Pigeonpea Growing Areas of Karnataka, India

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Keywords

Pigeon pea, sterility mosaic disease, incidence, germplasm

Article Info

Received:
21 September 2024
Accepted:
28 October 2024
Available Online:
10 November 2024

A B S T R A C T

A roving survey was undertaken in major pigeonpea growing areas of Karnataka to collect SMD infected samples showing different kinds of symptoms on different varieties and also incidence of SMD during *Kharif* 2015 and 2016. The results revealed that the incidence during the year 2015, maximum average incidence of 61.55 per cent was recorded in Yadagiri district and minimum average incidence was recorded in Chamarajanagar district with 1 per cent. Whereas during the year 2016, maximum average incidence of 47.66 per cent was recorded in Yadagiri district and minimum average incidence was recorded in Hassan district with 2.80per cent incidence.

Introduction

Pigeonpea [*Cajanus cajan* (L.) Millspaugh] is a short lived legume belonging to *Cajaninae* sub tribe of the economically most important leguminous tribe *Phaseoleae*. It is a multipurpose grain legume crop grown extensively for food in the Asian and African countries. India is considered as the primary centre of origin for pigeonpea due to the presence of ample variability in local germplasm and wild relatives (Saxena, 2008).

In recent years, the crop is gaining importance due to its inherent ability to perform well under marginal input conditions and also its adaptability to withstand drought and other abiotic stresses. In India, pigeonpea is cultivated in an (area of about 36.3 lakh ha with an annual production of 27.6 lakh tonnes averaging a productivity of 760.33 kg ha-1 (Anon., 2016). The pigeonpea seed serves as the major dietary protein source with more than 30 per cent of protein for large populations in the semi-arid tropics.

Although India leads the world both in area and production of pigeonpea, its productivity is lower than the world average. It is the most versatile grain legume crop grown in the semi-arid tropical and subtropical regions between 25° N and 30° S in Asia, Africa and the America. In India, it is one of the very important grain legumes and occupies second position in area and production next to chickpea. It is mainly grown in the states of Maharashtra, Karnataka, Andhra Pradesh, Uttar

Pradesh, Madhya Pradesh and Gujarat. Although, India leads the world both in area and production of pigeonpea, its productivity is lower than the world average which may be attributed to various abiotic (e.g. drought, salinity and water-logging) and biotic (e.g. diseases like Fusarium wilt, sterility mosaic and insects like pod borers) factors. Among diseases, Fusarium wilt and sterility mosaic diseases are the major constraints to pigeonpea production worldwide.

This is a matter of concern since the domestic demand of pigeonpea is rapidly increasing. Sterility mosaic disease (SMD), considered as the "green plague of pigeonpea" caused by *pigeonpea sterility mosaic virus* (PPSMV) and the virus is transmitted by the vector eriophyid mite, *Aceria cajani* Channa Basavanna (Kannaiyan *et al.,* 1984) is one of the major biotic factors, which leads to heavy yield losses and hence poses a big challenge for pigeonpea production in the Indian subcontinent.

More than 90 per cent of the crop would be lost if it occurs at the early stage of the crop growth (Bhaskaran and Muthiah, 2005). Hence the present investigations were carried out to know the more severely affected places in northeastern Karnataka.

Materials and Methods

A roving survey was undertaken in major pigeonpea growing areas of Karnataka to collect SMD infected samples showing different kinds of symptoms on different varieties and also incidence of SMD during *Kharif* 2015 and 2016. Further the collected SMD isolates with distinct symptom were grouped. The grouping was based on symptom *viz.,* severe mosaic, mild mosaic, ring spot symptom, complete sterility and partial sterility.

The per cent disease incidence was calculated based on the number of plants infected out of total plant examined in each sector.

$$\text{Disease incidence} = \frac{\text{Number of plants infected}}{\text{Total number of plants examined}} \times 100$$

Observations were also recorded on area under the crop, stage of the crop, variety grown, cropping system followed and type of symptoms produced.

Results and Discussion

Survey and collection of PPSMV isolates collected from major pigeonpea growing areas of Karnataka during *Kharif* 2015 and 2016

A roving survey was under taken to know the incidence of SMD in major pigeonpea growing areas of Karnataka *viz*., Bengaluru urban, Bengaluru rural, Ramnagar, Chikkbalapur, Kolar, Chitradurga, Kalburgi, Bidar, Chamrajnagar, Hasan, Mandya, Mysuru, Yadgiri and Tumkur districts. Pigeonpea was grown as a sole crop in Yadagiri, Kalburgi, Bidar and parts of southern Karnataka and as intercrop in most of the southern districts of Karnataka. The disease incidence was maximum in sole crop as compared to the intercropped pigeonpea. Further the collected SMD isolates with distinct symptom were grouped.

The grouping was based on symptoms *viz.,* severe mosaic, mild mosaic, ringspot symptom, complete sterility and partial sterility. The results on incidence of SMD and grouping of isolates collected during *Kharif* 2015 are presented in Table 1. During survey different kind of symptoms were recorded on SMD infected plant and they were grouped on the basis of symptom exhibited on the infected plant. In Bengaluru rural district, the minimum incidence of SMD (8.70%) was recorded in village, Honnaghatta of Doddabalapur taluk and maximum disease incidence (61.80%) was recorded in Aravesandra village of Nelamangala taluk. Varieties such as BRG 1, BRG 2were exhibited different kinds of symptoms and they were grouped into mild mosaic, ringspot and severe stunting. In Ramnagar district, lowest disease incidence (3.10%) of SMD was recorded in Hulekatte, whereas highest disease incidence (62.50%) was recorded in Karenahalli village of Magadi taluk and varieties such as BRG 1, BRG 2, BRG 5 expressed ringspot, complete sterility, severe chlorosis, stunting of plants and partial sterility. The highest incidence of 49.10 per cent was noticed at Agalagurki, whereas lowest incidence (2.10%) was recorded at Ellodu village of Chikkbalapur district. The grown varieties such as Local, BRG 1 and 2 expressed severe chlorosis, mild chlorosis, partial sterility, ring spot and stunting of plants. In Kolar district, maximum incidence of 15.30per cent was recorded at Kolartaluk and minimum incidence of zero per cent was recorded at Srinivaspur and BRG 5 shown severe stunting and mild mosaic symptoms. The lowest incidence of 8.5 per cent was recorded at Nettikeri village of Gubbi taluk and highest incidence was

recorded at Chikkanahalli village of Sirataluk, Tumkur district. BRG 2, TTB 7, TS 3R and BRG 1 expressed bushy appearance, reduction in leaf size, partial and complete sterility and severe chlorosis.

The lowest disease incidence (5.0%) was recorded at Manalli village of Bidar taluk and highest disease incidence (100%) was noticed at Narayanapur village, Aurad taluk of Bidar district. Varieties like Maruti, Gulyal local, TS 3 R, Benur local were expressed partial and complete sterility and severe chlorosis.

In Kalaburagi district, the minimum disease incidence was recorded in Hangaraga village of Jevargi and maximum disease incidence was noticed in Dandhothi village of Chittapur taluk. The highest disease incidence was noticed in Sagar (100%) and minimum disease incidence was recorded in Vibuthihalli (5.0%). Varieties *viz*., TTB 7, HY 3C, BRG 1 and local varieties expressed severe, mild chlorosis, partial sterility, ringspot and stunting of plants.

The results on survey carried out during *Kharif* 2016, where Bengaluru rural district recorded an average of 14.5 per cent disease incidence, the maximum incidence of 35.8 per cent and minimum incidence of 5.0 per cent was recorded at Vishwanathpur village. The minimum disease incidence was noticed at Hulekatte village, Magadi taluk of Ramnagar district and maximum incidence was found at Karenahalli village.

The average disease incidence (15%) was recorded at Benakanahalli village of Chikkabalapur, maximum disease (49.1%) was noticed at taluk Chikkabalapur and minimum disease incidence was noticed at Gowribidanur of Chikkabalapur district. In Kolar minimum disease incidence (11.10%) was observed in Kunigal and zero per cent was recorded at Kambalapalli village.

In villages of Hassan district, 0-2.5% disease incidence was noticed. The highest disease incidence (51.3%) was noticed in Chikkanahalli village of Tumkur district and lower disease incidence was recorded in Nettikere village. BRG 1, BRG 2, TTB 7 and HY 3C and observed symptoms like severe, mild chlorosis, partial sterility, ringspot and stunting of plants, complete sterility on pigeonpea. The minimum disease incidence was noticed in Chitradurga district of Gannayakanahalli and maximum was recorded in Kaparahalli of Challakere taluk. In Bengaluru urban district, higher disease was recorded at village Shivakote and lower disease incidence was noticed in Singanayakanahalli. In Mysuru district very less disease incidence was noticed 0-3%. Grown varieties like BRG 1, BRG 2, TTB 7 and HY 3C and observed symptoms like severe, mild chlorosis, partial sterility, ringspot and stunting of plants, complete sterility on pigeonpea. Similar findings were found, in Bidar district, Janti village recorded maximum disease incidence also and minimum disease incidence was recorded at Santhpur village.

Similarly, Kalburgi district recorded the SMD incidence inthe range of maximum disease incidence was recorded at Udagi village, Sedum taluk of Kalburgi district (84.10%) and minimum disease incidence was observed at Chandapur village of Chincholi taluk. The average disease incidence was recorded at Rukmapur village of Surpur taluk, minimum was noticed at Vibuthihalli and maximum was noticed at Rangampet village of Yadgiri district. In this district different varieties were grown and they expressed different kind of symptoms like mild mosaic, bushy appearance, reduction in leaf size, partial and complete sterility, severe chlorosis and ring spot on TS-3R, Benurlocal, Maruthi and Asha varieties.

The average per cent disease incidence of different districts surveyed during *Kharif* 2015 and 2016 was calculated and presented in Table 3, Figure 1 and Plate 1. During the year 2015, maximum average incidence of 61.55 per cent was recorded in Yadagiri district and minimum average incidence was recorded in Chamarajanagar district with 1 per cent.

During the year 2016, maximum average incidence of 47.66 per cent was recorded in Yadagiri district and minimum average incidence was recorded in Hassan district with 2.80 per cent incidence. Reddy *et al.,* (1990) also noticed the presence of off-season pigeonpea harbouring SMD virus and mite vector in southern parts of Karnataka where off-season pigeonpea plants were grown along the bunds of cabbage and mulberry fields.

Survival of mite vector and the SMD virus on pigeonpea plants around sugarcane field bunds which were allowed to continue growing throughout the off season for various reasons and traced the survival of SMD virus and mite on wild pigeonpea (*Cajanas scarabaioidis* var*s carabaiodes*) and also observed existence of mite perennial pigeonpea, in mango, orange, grape and coconut orchards and on bunds of irrigated fields which were prevalent in the states of Andhra Pradesh, Gujarat and Karnataka (Reddy *et al.,* 1993).

Table.1 Incidence of Sterility Mosaic disease (SMD) of pigeonpea in major growing areas of Karnataka during Kharif 2015

Sl. No.	Districts	Taluks	Villages	Area (ha)	Varieties	PDI	Cropping pattern	Symptoms
1.	Bengaluru rural	Doddaballapur	Honnaghatta	2.00	BRG 2	27.50	Sole crop	**SM**
					BRG 1	8.70	Sole crop	**MM**
			Neraleghatta	2.40	BRG 2	15.80	Sole crop	**SM**
					BRG 1	10.50	Sole crop	**MM**
		Nelamangala	Aravesandra	3.00	Local	58.20	Sole crop	**SM**
					BRG 2	61.80	Sole crop	**SM**
					BRG 1	14.90	Sole crop	**MM**
		Devanahalli	Channarayapatna	3.50	BRG 1	15.10	Sole crop	**MM**
					HY 3C	23.50	Sole crop	**SM**
			Vijayapura	7.00	BRG 1	20.00	Intercrop	**MM**
					BRG 2	25.90	Intercrop	**SM**
2.	Ramanagar	Magadi	Guddalahalli	6.00	Local	50.00	Sole crop	**SM**
					Local	51.50	Sole crop	**SM**
			Hulekatte	2.00	BRG 1	6.10	Sole crop	**MM**
					BRG 1	17.00	Intercrop	**MM**
			Karenahalli	5.00	BRG 2	62.50	Intercrop	**SM**
					BRG 5	15.00	Intercrop	**MM**
		Kanakapura	Agrahara	4.00	BRG 1	10.00	Sole crop	**MM**
3.	Chikballapur	Bagepali	Babenayakanapalli	2.00	Local	25.00	Intercrop	**SM**
					BRG 2	11.20	Intercrop	**MM**
			Mallepalli	7.00	Local	26.10	Sole crop	**SM**
					BRG 1	7.300	Intercrop	**MM**
			Yarraganapalli	3.00	Local	8.10	Sole crop	**MM**
		Gudibande	Ellodu	2.00	BRG 1	2.50	Sole crop	**MM**
					BRG 2	**13.10**	**Sole crop**	**MM**

Sl. No.	Districts	Taluks	Villages	Area (ha)	Varieties	PDI	Cropping pattern	Symptoms
		Chikkballapur	Agalagurki	1.00	BRG 1	49.10	Sole crop	**SM**
				4.50	Local	29.80	Inter crop	**SM**
4.	Tumakuru	Sira	Chikkanahalli	3.50	BRG 2	82.30	Intercrop	**SM**
			Gomaranahalli	3.20	BRG 1	38.90	Intercrop	**SM**
			Thalagunda	1.30	TS 3 R	32.50	Intercrop	**SM**
		Gubbi	Nettikere	1.50	BRG1	8.50	Sole crop	**MM**
5.	Hassan	Channarayapattana	Belaguli	2.50	BRG 1	10.00	Sole crop	**SM**
			Kalenahalli	3.00	BRG 1	22.30	Sole crop	**SM**
			Gowdagere	1.50	BRG 1	3.10	Sole crop	**MM**
		Arasikere	Byrapura	2.00	BRG 1	7.10	Sole crop	**MM**
			Doddaghatta	3.80	BRG 2	14.5	Intercrop	**SM**
6.	Chitradurga	Hiriyur	Gannayakanahalli	3.00	BRG 1	7.50	Intercrop	**MM**
			Hariyabbe	6.00	BRG 2	20.1	Intercrop	**SM**
		Challakere	Kaparahalli	3.50	BRG 1	25.7	Inter crop	**SM**
			Hulikunte	2.50	Local	22.5	Inter crop	**SM**
7.	Bengaluru urban		Singanayakanahali	1.00	BRG 1	2.00	Sole crop	**SM**
			Hesaraghatta	1.00	BRG 1	45.0	Sole crop	**SM**
			Banavara	0.25	BRG 2	5.20	Sole crop	**SM**
			Shivakote	1.90	BRG 2	58.9	Sole crop	**SM**
			Nagadasanahali	2.00	BRG 5	7.50	Sole crop	**SM**
8.	Mysuru	Mysuru	Ganuru	1.00	BRG 1	12.0	Intercrop	**SM**
		H.D.Kote	Yadaethorae	2.50	BRG 1	1.50	Sole crop	**SM**
			Madapura	2.90	BRG 1	3.40	Sole crop	**MM**
		Hunsur	Nellurupala	1.50	Local	14.5	Sole crop	**SM**
			Azadhnagar	0.25	BRG 2	18.5	Sole crop	**SM**
		Piriyapatna	**Kalbetta**	**1.50**	**HY 3C**	**0.00**	**Sole crop**	**NS**

Sl. No.	Districts	Taluks	Villages	Area (ha)	Varieties	PDI	Cropping pattern	Symptoms
9.	Chamarajnagara		Udigala	1.20	TTB 7	5.10	Sole crop	**SM**
			Veeranapura	0.75	Local	2.10	Intercrop	**SM**
10.	Mandya	Maddur	Gejjalagere	0.25	Local	2.20	Intercrop	**MM**
		Srirangapatna	Tubinagere	2.50	HY 3C	5.20	IC with field bean	**MM**
			Garudanaukkala	0.70	Local	11.50	IC with cowpea	**MM**
			Korsadipura	1.00	TTB 7	32.10	Sole crop	**SM, MM**
11.	Bidar	Bidar	Janawada	3.50	Maruthi	34.20	Sole crop	**SM**
			Manalli	4.20	BSMR 736	2.90	Sole crop	**MM**
		Basavakalyan	Rajeshur	3.00	BSMR 736	5.00	Sole crop	**SM**
			Basavakalyan	2.50	Maruthi	79.00	Sole crop	**SM**
		Aurad	Narayanpur	3.50	Gulyal local	100	Sole crop	**SM**
			Janti	3.90	Gulyal local	51.00	Sole crop	**SM**
			Santhpur	3.50	GRG 8	6.70	Sole crop	**SM**
			Mungnal	2.50	Benur -local	7.00	Sole crop	**SM**
		Bhalki	Ahmadabad	1.50	BSMR 736	5.50	Sole crop	**SM**
			Gorta	3.50	Maruthi	11.0	Sole crop	**SM**
			Byalalli	4.20	Gulyal local	2.80	Sole crop	**MM**
			Halgorta	2.50	Maruthi	12.40	Sole crop	**SM**
		Humnabad	Udbal	4.20	Gulyal local	18.10	Sole crop	**SM**
12.	Kalburgi	Kalburgi	Sinnur	7.50	Maruthi	85.00	Sole crop	**SM**
			Parthabad	3.50	BRG 2	9.20	Sole crop	**SM**
			Kulkur	4.00	Gulyal local	38.10	Sole crop	**SM**
			Itga	2.30	Gulyal local	42.00	Sole crop	**SM**
			Basavapatna	2.80	BSMR 736	20.00	Sole crop	**SM**
		Chitthapur	Gunsgurthi	3.50	Asha	6.70	Sole crop	**SM**
			Dandothi	**1.50**	**GRG 8**	**8.00**	**Sole crop**	**SM**

Sl. No.	Districts	Taluks	Villages	Area (ha)	Varieties	PDI	Cropping pattern	Symptoms
		Sedum	Malkhed	5.50	Maruthi	20.00	Sole crop	**SM**
			Mudhol	2.50	Gulyal local	5.60	Sole crop	**SM**
			Udgi	3.30	Gulyal local	100	Sole crop	**SM**
		Chincholi	Chandramapalli	5.50	Benur local	20.00	Sole crop	**MM, SM**
			Sugur	4.20	Maruthi	100	Sole crop	**SM**
			Chandapur	2.50	Maruthi	11.00	Sole crop	**SM**
			Inoli	4.20	BSMR736	13.00	Sole crop	**SM**
		Aland	Tadkal	3.50	BSMR 736	1.50	Sole crop	**SM**
			Kajuri	3.00	Maruthi	14.00	Sole crop	**SM**
			Belamagi	3.50	Bennur local	11.00	Sole crop	**MM**
		Afzalpur	Chowdapur	4.60	Asha	14.00	Sole crop	**SM**
			Gobbur	4.50	BSMR 736	8.80	Sole crop	**SM**
			Ghattargi	3.50	Bennur local	7.80	Sole crop	**SM**
			Ganagapur	3.00	Bennur local	14.50	Sole crop	**SM**
		Jewargi	Ijeri	3.50	Bennur local	5.40	Sole crop	**SM**
			Hangarga	2.50	Bennur local	2.00	Sole crop	**SM**
			Kachapur	4.40	GRG 8	20.10	Sole crop	**MM**
13.	Yadagiri	Shahapur	Sagar	2.50	Maruthi	100	Sole crop	**SM**
			Hattigudur	3.50	Bennur local	35.10	Sole crop	**SM**
			Vibuthihali	2.50	GRG 8	5.10	Sole crop	**MM**
		Shorapur	Shantapur	3.10	Maruthi	98.00	Sole crop	**SM, MM**
			Rukmapur	2.50	Bennur local	31.00	Sole crop	**SM**
			Rangampet	**1.50**	**Maruthi**	**100**	**Sole crop**	**SM**

SM- Sever mosaic, MM- mild mosaic, NS- No symptom, IC- Intercrop and Per cent Disease Incidence (PDI)

Table.2 Incidence of SMD in major pigeonpea growing areas of Karnataka during *kharif*2016

Sl. No	Districts	Taluks	Villages	Area (ha)	Varieties	Symptom expression	PDI	Cropping pattern	Symptoms
1	Bangalore rural	Doddaballapura	Hosahalli	2.5	BRG1	Partial sterility	5.9	Sole crop	SM
			Sasalu	1.5	BRG2	Ringspot	14.5	Sole crop	MM
			Sakkaregollahalli	1.9	BRG1	Stunting of plants	1.8	Sole crop	SM
			Tubagere	2.5	TTB-7	Complete sterility	35.8	Sole crop	MM
		Nelamangala	Aravesandra	1.5	HY-3C	Severe chlorosis	11.5	Sole crop	SM
			Bellikote	0.75	BRG1	Mild chlorosis	15.0	Sole crop	SM
		Devanahalli	Vishwanathpura	1.5	HY-3C	Partial sterility	5.0	Sole crop	MM
			Channarayapatna	1.5	BRG1	Ringspot	15.1	Sole crop	MM
			Budhigere	1.5	HY-3C	Stunting of plants	23.5	Sole crop	SM
			Vijayapura	1.6	TTB7	Partial sterility	12.0	Intercrop	MM
				2.5	BRG1	Ringspot	25.9	Intercrop	SM
2	Ramanagar	Magadi	Magadi	1.5	TTB-7	Stunting of plants	50.0	Solecrop	SM
			Gejjegaraguppe	1.5	Local	Complete sterility	51.5	Sole crop	SM
			Hulekatte	2.5	BRG2	Severe chlorosis	6.1	Sole crop	MM
			Kudur	1.75	BRG1	Mild chlorosis	7.0	Intercrop	MM
			Karenahalli	2.1	BRG1	Partial sterility	62.5	Intercrop	SM
			Madbal	1.75	TTB-7	Ringspot	15.0	Intercrop	MM
		Kanakapura	Agrahara	1.3	BRG2	Stunting of plants	10.0	Sole crop	MM
			Devegowdanahalli	1.5	TTB-7	Ringspot	24.5	IC with cowpea	SM,MM
			Shivanahalli	1.5	TTB-7	Mild mosaic	51.4	Intercrop	SM
3.	Kolar	Kolar	Tamaka	1.5	Local	Partial sterility	5.3	Intercrop	MM
		Srinivasapura	Kambalapalli	2.5	BRG5	Ringspot	0.0	Sole crop	NS

		Kunigal	Dasanapura	1.5	Local	Stunting of plants	11.1	Sole crop	SM
4.	Tumakuru	Sira	Chikkanahalli	1.2	BRG2&1	Complete sterility	51.3	Intercrop	SM
			Gomaranahalli	1.5	TTB7	Severe chlorosis	28.9	Intercrop	SM
			Thalagunda	2.5	TS 3R	Mild chlorosis	12.5	Intercrop	SM
		Gubbi	Nettikere	1.5	BRG2	Partial sterility	3.5	Sole crop	MM
					Local	Mild mosaic	8.9	Inter crop	MM
5.	Hassan	Channarayapattana	Belaguli	2.5	BRG2	Ring spot	1.0	Sole crop	SM
			Kalenahalli	1.0	TTB7	Ringspot	2.3	Sole crop	SM
			Gowdagere	1.5	BRG2	Mild mosaic	5.1	Sole crop	MM
		Arasikere	Byrapura	2.1	BRG2	Severe stunting	2.1	Sole crop	MM
			Doddaghatta	1.5	BRG2	Mild mosaic	3.5	Intercrop	SM
6.	Chitradurga	Hiriyur	Gannayakanahalli	0.75	BRG1	Ringspot	4.5	Intercrop	MM
			Hariyabbe	2.3	TTB7	Bushy appearence	12.1	Intercrop	SM
		Challakere	Kaparahalli	1.5	TTB7	Reduction in leaf size	15.7	Inter crop	SM
			Hulikunte	2.5	Local	Partial sterility	12.5	Inter crop	SM
7.	Bangalore urban		singanayakanahali	1.5	BRG1	Mild mosaic	2.5	Sole crop	SM
			Hesaraghatta	1.5	TTB7	Complete sterility	15.0	Sole crop	SM
			Banavara	1.5	BRG1	Severe chlorosis	5.2	Sole crop	SM
			Shivakote	1.5	TTB7	Mild chlorosis	18.9	Sole crop	SM
			Nagadasanahali	2.4	HY 3C	Partial sterility	11.5	Sole crop	SM
8.	Mysore	Mysore	Ganuru	3.0	TTB7	Ringspot	5.2	Intercrop	SM
		H.D.Kote	Yadaethorae	2.5	HY 3C	Stunting of plants	4.5	Sole crop	SM
			Madapura	2.5	BRG1	Complete sterility	8.4	Sole crop	MM
		Hunsur	Nellurupala	1.8	Local	Severe chlorosis	7.5	Sole crop	SM

			Azadhnagar	1.5	TTB7	Mild chlorosis	1.5	Sole crop	SM
		Piriyapatna	Kalbetta	1.5	HY-3C	Partial sterility	4.5	Sole crop	MM
9.	Chamarajnagara		Udigala	1.2	TTB-7	Ringspot	7.1	Sole crop	SM
			Veeranapura	2.75	Local	Stunting of plants	9.1	Intercrop	SM
10	Mandya	Maddur	Gejjalagere	1.25	Local	Mild mosaic	1.2	Intercrop	MM
		Srirangapatna	Tubinagere	1.5	HY-3C	Ring spot	2.2	IC with fieldbean	MM
			Garudanaukkala	1.75	Local	Ringspot	1.5	IC with cowpea	MM
			Korsadipura	1.5	TTB-7	Mild mosaic	12.1	Sole crop	SM,MM
			Gorta	6.5	TS-3R	Severe chlorosis	13.0	Sole crop	SM
			Byalalli	3.2	TS-3R	Mild chlorosis	1.5	Solecrop	MM
			Halgorta	3.5	TS-3R	Partial sterility	5.4	Solecrop	SM
11	Gulbarga	Gulbarga	Sinnur	3.5	Maruthi	Stunting of plants	65	Sole crop	SM
			Parthabad	2.5	TS-3R	Partial sterility	5.2	Solecrop	SM
			Kulkur	3.1	Gulyallocal	Ringspot	31.1	Sole crop	SM
			Itga	1.3	Gulyal local	Stunting of plants	25.7	Solecrop	SM
			Basavapatna	3.8	BSMR-736	Complete sterility	10.4	Solecrop	SM
		Chitthapur	Gunsgurthi	1.5	Asha	Severe chlorosis	3.7	Solecrop	SM
			Dandothi	4.5	TS-3R	Mild chlorosis	5.1	Solecrop	SM
		Sedum	Malkhed	2.5	Maruthi	Partial sterility	16.1	Solecrop	SM
			Mudhol	4.5	TS-3R	Ringspot	1.5	Solecrop	SM
			Udgi	1.35	Gulyallocal	Stunting of plants	84.1	Solecrop	SM
		Chincholi	Chandramapalli	3.5	Benur local	Ringspot	11	Solecrop	MM,SM
			Sugur	2.2	Maruthi	Mild mosaic	80	Sole crop	SM
			Chandapur	1.5	TS-3R	Severe stunting	1.0	Solecrop	SM

			Inoli	3.25	BSMR736	Mild mosaic	5.3	Sole crop	SM
		Aland	Tadkal	2.5	TS-3R	Ringspot	1.1	Solecrop	SM
			Kajuri	1.3	TS-3R	Bushy appearence	1.4	Solecrop	SM
			Belamagi	1.5	Benur local	Reduction in leaf size	21.1	Solecrop	MM
		Afzalpur	Chowdapur	5.6	Asha	Partial sterility	12.5	Solecrop	SM
			Gobbur	4.3	TS-3R	Mild mosaic	2.1	Solecrop	SM
			Ghattargi	4.5	Benur local	Complete sterility	4.1	Solecrop	SM
			Ganagapur	4.3	Benur local	Severe chlorosis	4.5	Solecrop	SM
		Jewargi	Ijeri	3.3	Benur local	Mild chlorosis	1.4	Sole crop	SM
			Hangarga	2.5	Benur local	Partial sterility	1.5	Sole crop	SM
			Kachapur	6.4	TS-3R	Ringspot	10.1	Sole crop	MM
12	Yadgiri	Shahapur	Sagar	3.5	Maruthi	Stunting of plants	67.8	Sole crop	SM
			Hattigudur	5..5	Benur local	Complete sterility	15.1	Sole crop	SM
			Vibuthihali	4.5	TS-3R	Severe chlorosis	9.1	Sole crop	MM
		Surpur	Shantapur	5.1	Maruthi	Mild chlorosis	78	Sole crop	SM,MM
			Rukmapur	2.5	Bennur local	Partial sterility	41.0	Sole crop	SM
			Rangampet	1.5	Maruthi	Mild mosaic	75.0	Sole crop	MM

SM- Sever mosaic, MM- mild mosaic, NS- No symptom, IC- Intercrop and Per cent Disease Incidence (PDI)

Table.3 Incidence of SMD of pigeonpea in major growing areas of Karnataka during *Kharif*2015 and 2016

Districts	No of talukas	Varieties grown	2015		2016	
			PDI (range)	PDI (average)	PDI (range)	PDI (average)
Bengaluru rural	3	BRG 1, BRG 2 Local, HY 3C	8.00-62.00	25.60	5.0-35.8	**14.00**
Ramnagar	2	Local, BRG 1 BRG 2, BRG 5	10.00-62.50	30.70	6.0-62.5	**22.40**
Chikkabalapura	3	Local, BRG 2, BRG 1	2.00-49.10	19.10	5.0-11.1	**-**
Tumkur	2	BRG 2, BRG 1 TS 3R	8.50-83.20	40.50	3.5-51.3	**21.00**
Hassan	2	BRG 1, BRG 2	3.10-22.30	11.40	1.0-4.5	**2.80**
Chitradurga	2	Local	7.50-25.70	15.10	2.5-15.7	**8.30**
Bengaluru urban	2	BRG 1, BRG 2, BRG 5	2.00-58.90	23.70	2.5-18.9	**12.60**
Mysuru	4	BRG 1, Local, BRG 2, HY 3C, TTB 7	1.00-2.90	9.98	1.5-8.4	**5.26**
Chamarajnagar	1	TTB 7, Local	0.75-1.20	1.00	1.2-9.1	**8.10**
Mandya	1	Local, HY 3C, TTB 7	0.75-2.50	12.70	1.5-12.1	**5.27**
Bidar	5	Maruthi, BRG 2, BSMR 7, Gulyal local, Benur local	2.80-100	25.70	5.5-21.5	**28.90**
Kalburgi	7	Maruthi, Gulyal local, BSMR 736, Asha, Gulyal local, Benur local	2.00-100	25.10	1.5-80	**20.70**
Yadgiri	**2**	**Maruthi, Benur local, Gulyal local, BSMR 736**	**5.10-100**	**61.50**	**9.1-75**	**47.60**

PDI -Per cent Disease Incidence

Figure.1 Incidence of SMD in major pigeonpea growing areas of Karnataka during*Kharif*2015 and 2016

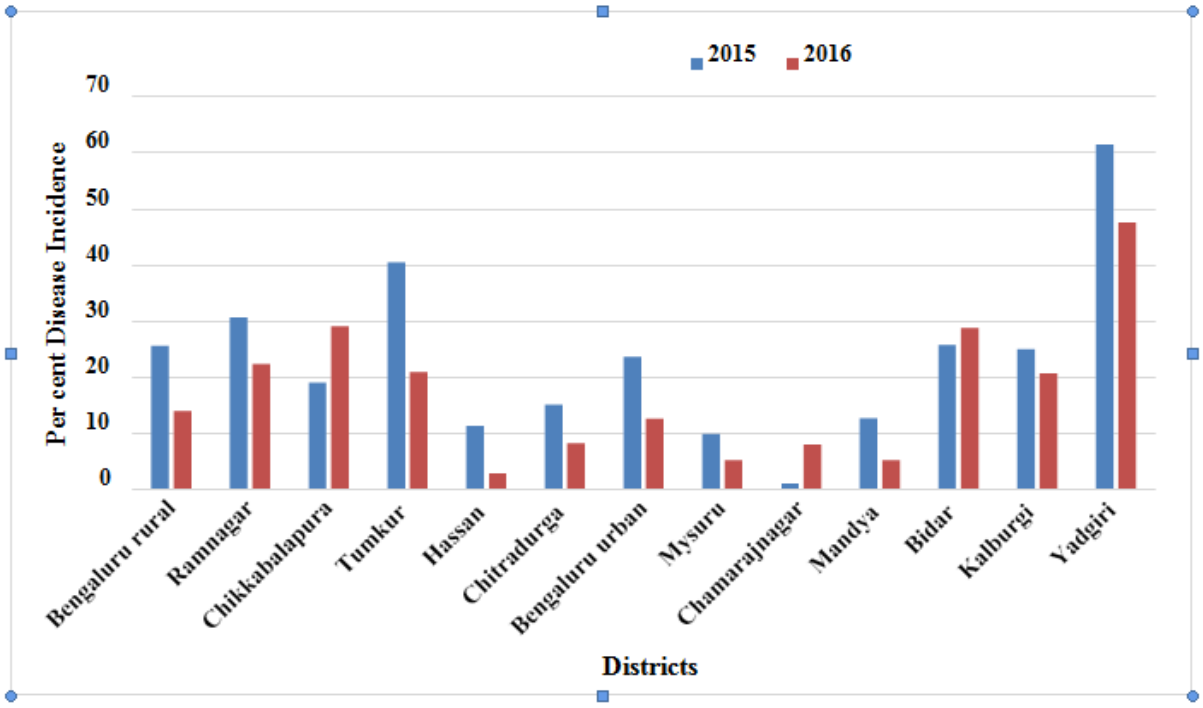

Plate.1 Pigeonpea field showing severe infection of sterility mosaic disease (SMD)

The present research findings are concordant with the observations made by Narayan *et al.,* (2000). One of the probable reasons contributing for SMD incidence in Bidar and Kalburgi districts may be attributed to the off-season survival of sterility mosaic pathogen in ratooned and perennial crop grown along the borders and bunds of sugarcane field in irrigated tracts and also pigeonpea flushes of the previous season crop which was commonly observed in SMD infested fields. The higher SMD incidence was noticed in Bidar district might have influenced the disease outbreak in adjoining taluks of Kalburgi district.

Vishwadhar *et al.,* (1995) reported variation in the incidence of SMD from location to location within a district may be attributed to climatic factors affecting the survival and multiplication of mite vectors in *Kharif* pigeonpea which were present during off season in the irrigated and protected fields from cattle, in the form of ratooned/ perennial/ summer pigeonpea.

Minimum temperature range of 10-25oC and maximum temperature range of 25 to 35oC was found congenial for buildup of mite population and temperature below10^{o}C and above 35oC were not congenial for vector and disease build up, respectively

Reddy *et al.,* (1990) during the survey noticed on the presence of off season pigeonpea in the form of ratooned growth, perennial pigeonpea and summer crops in the states of Andhra Pradesh, Gujarat, Karnataka and Tamil Nadu. Periodical observations on perennial plants grown at Kanpur have revealed the survival of *Aceria cajani* in the vegetative buds and growing points where they escape to extreme and remain hidden in relatively cooler place due to continued transevaporation (Vishwadhar *et al.,* 1994).

Moreover Bidar district falls under north eastern transitional zone with an annual rainfall of 1020mm per annum and has a cool and humid climatic condition with lower temperatures which probably might help in increased population of mite vectors in turn receiving more SMD epidemics in Bidar district over years. Roving survey was conducted to know the extent of severity of sterility mosaic disease (SMD) of pigeon pea in three districts of northeastern Karnataka *viz* Bidar, Kalburgi and Yadgir. The results revealed that the incidence varied from 9.50 to 34.50 percent during *Kharif* 2015. Bidar district recorded highest incidence of the disease (26.38%) followed by Kalburgi (24.08%) and the least incidence was at Yadgiri (10.81%). The highest incidence of 34.50 per cent was recorded at the Rajgira village of Bidar Taluk (Sudharani *et al.,* 2017).

Author Contributions

N. M. Prabhavathi: Investigation, formal analysis, writing—original draft.

Data Availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethical Approval Not applicable.

Consent to Participate Not applicable.

Consent to Publish Not applicable.

Conflict of Interest The authors declare no competing interests.

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How to cite this article:

Prabhavathi, N. M. 2024. Studies on Prevalence and Morphological Symptom Characterisation of Pigeonpea Sterility Mosaic Virus Isolates from Major Pigeonpea Growing Areas of Karnataka, India. *Int.J.Curr.Microbiol.App.Sci.* 13(11): 228-242. **doi:** https://doi.org/10.20546/ijcmas.2024.1311.026