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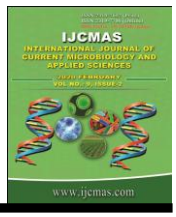

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Etiology and Symptomatology, Survey and Host Range Studies of Yellow Mosaic Disease on Horsegram Transmitted by Whitefly (*B. tabaci*) in North Eastern Karnataka, India

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A B S T R A C T

Yellow mosaic disease (YMD) on horsegram caused by begomovirus belongs to family geminiviridae is an emerging threat for crop cultivation in peninsular India and in many parts of Karnataka. The present etiological studies indicated that the symptoms characterized by faint yellow discoloration on the young leaves in the beginning as disease progresses, the leaves show characteristic symptoms of mottling. The mottling are irregular, small, greenish yellow in colour and intermixed with normal green patches, later on the mottling become enlarged and turn bright yellow and eventually become completely bleached. The average incidence of horsegram yellow mosaic disease (HgYMD) varied from 10.68 to 44.91% in major surveyed areas of north eastern Karnataka. The maximum incidence (44.91%) was recorded in Kushtagi taluk of Karnataka. Among the 15 host plants belonging to diversified families tested for host range, blackgram (*Vigna mungo*), greengram (*V. radiata*), soybean (*Glycine max*), pigeon pea (*Cajanus cajana*), *Croton bonplandianum*, *Parthenium hysterophorus*, *Malvestrunm coromandelium* and *Alternenthera sessile* were shown to be susceptible.

Keywords

Horsegram, Yellow mosaic disease, Geminivirus, Whitefly, Incidence

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Introduction

Horsegram (*Macrotyloma uniflorum* (Lam.) Verde. Syn. Dolichos biflorus), commonly known as kulthi, is one of the hardiest and drought tolerant crops, grown extensively in peninsular India as poor man's pulse crop. It is an under exploited grain legume with great potential in sustainable agriculture as it enriches soil considerably by fixing

atmospheric nitrogen and increasing the organic matter of soil. It is the only choice crop of the farmers for delayed sowing due to late receipt of rains. It is one of the important minor pulse crops in India and is cultivated in an area of 3.26 lakh hectare with a production of 1.17 lakh tones. Horsegram is one of the important pulse crops being cultivated over a larger area in many dry land regions of Karnataka. Crop is known to suffer from several diseases including fungal, bacterial and viral diseases.

Among the diseases, Yellow mosaic disease (YMD) caused by begomovirus belongs to family geminiviridae is one of the emerging threat for crop cultivation in peninsular India and in many parts of Karnataka. Yellow mosaic disease transmitted by whitefly *B. tabaci* (Gennadius) more prevalent in most parts of Indian subcontinent (Varma and Malathi, 2003). Yellow mosaic disease transmitted by whitefly *B. tabaci* (Gennadius) more prevalent in most parts of South India (Muniyappa and Reddy, 1976). The disease incidence ranged from 50 to 100 per cent in both summer and early rainy season crops causing substantial loss in grain yield (Muniyappa *et al.,* 1975). The increasing spread of the horsegram yellow mosaic disease due to increase in *B. tabaci* population resulted in almost complete loss of the crop during summer (Muniyappa *et al.,* 1976; Rajkumar, 2006 and Prema, 2013). Host range studies with *Tomato leaf curl virus* (ToLCV) (Muniyappa *et al.,* 2000), *Pumpkin yellow vein mosaic* in pumpkin (Maruthi *et al.,* 2007), *Hibiscus leaf curl virus* in Hibiscus (Rajeshwari *et al.,* 2005), *Croton leaf curl virus* in cotton (Mahesh *et al.,* 2010) and *Mungbean yellow mosaic virus* in Greengram (Deepa *et al.,* 2017) revealed that begomo viruses have wide host compatibility, however, their infection and further symptoms expression varied between the host plants.

In the recent years, YMD on horsegram has been found severely affected and its incidence reached 80 per cent in different areas of Karnataka. However, work done and literature available on occurrence and distribution of YMD of horsegram from North Eastern parts of Karnataka is very scanty, mode of spread and its relationships with the vector whitefly *B. tabaci* have not been studied. Further the sources of reservoir hosts of the virus and the vector in relation to disease severity also not been documented from North Eastern parts of Karnataka. Hence with these backdrops, the present study on occurrence and distribution, symptomatology and host range studies on HgYMD were taken up.

Materials and Methods

Disease incidence

The roving survey was carried out to assess the status of yellow mosaic disease incidence on horsegram in major horsegram growing areas of north eastern Karnataka such as Koppal, Raichur and Ballari during *Rabi* 2018. From each selected district, four talukas and from each taluk five villages were monitored. From each village, two horsegram fields are selected and randomly 10 m x 10 m area was observed for disease incidence. Disease incidence was assessed by counting number of symptomatic plants (symptoms *viz.* chlorosis, mosaic, mottling, reduction in leaf size and stunted growth) over total number of plants (including both symptomatic and non-symptomatic) in randomly selected plots at each location. During the survey, symptomatic leaf samples were collected from each location and designated as separate isolate for further studies. The disease incidence was calculated based on the number of plants infected out of total plant population observed.

$$\text{Disease incidence (\%)} = \frac{\text{Number of plants infected in a row}}{\text{Total number of plants in a row}} \times 100$$

To Develop GIS maps for spatial variation of *Horsegram yellow mosaic virus* (HYMV) incidence in horsegram in North Eastern Karnataka

To develop spatial Geographic positioning system (GPS) maps for the distribution and severity of YMV disease on horsegram in selected districts of North Eastern Karnataka, field survey was carried out in major growing areas of Raichur, Ballari and Koppal districts. The incidence of the disease in each location was calculated as per the formula mentioned in 3.1 based on disease rating scale (0-5) (Bashir, 2005).

(0: No incidence; 1: 1-10%; 2: 11-20%; 3: 21-30%: 4: 31-50%; 5: >50 %).

The methodology adopted for generation of spatial GIS maps is given below.

Site selection

In each of the selected district, four taluks and within each taluk, minimum of five villages and in each village 100 sq. m areas of two locations were identified to record the yellow mosaic distribution based on the disease incidence and severity scale.

Data collection during *Rabi* 2018-19

Initially the collection of data at different places of selected districts during *Rabi* 2018-19 was planned to assess the spatial variability of horsegram yellow mosaic disease. Further, the survey was carried out by using global positioning system (GPS) (Trimble MAK – Geo XH), where the co-ordinates (latitudes and longitudes) were collected at each sampling point to map the spatial distribution of horsegram yellow mosaic disease. Each site was geo referenced in the Universal Transverse Mercator (UTM) co-ordinate system with a GPS for spatial analysis.

GPS data import

The collected sample locations from GPS were imported using path finder software. Since the projection system of collected locations were pre-defined in the GPS, the imported sample points were found within the respective villages administrative boundary (having similar projection and datum i.e., UTM, WGS 84), when imported in the GIS environment.

Data attachment and mapping

The field observations on YMV disease distribution and severity were fed in excel sheet with proper labelling for each observation. The unique ID was added and the physical ID was created along with the sample locations imported in the Arc GIS environment. Further the collected field data were attached to the respective GPS location points using unique ID 121 relationships in Arc GIS 2010. The disease incidence of yellow mosaic virus was displayed through unique symbol to understand the spatial distribution of yellow mosaic virus. The maps of spatial distribution of yellow mosaic virus in surveyed districts *viz.*, Raichur, Ballari, and Koppal are given in the fig 3, 4, 5, 6. The DGPS used in this study is the latest version (GeoXH) from Trimble, which is enabled to receive the satellite signals from GNSS which will give more accurate location reading.

Computer Software

Arc GIS 10 software from Sujal project laboratory, College of Agriculture, Raichur was used for the processing and analysing the data.

Host range studies

Healthy seedlings of horsegram plants and other pulses of family Leguminaceae and weed hosts belong to Euphorbiaceae, Asteraceae, Amaranthaceae, Phyllanthaceae and Malvaceae were selected and raised in an insect proof glasshouse. Seedlings at the two leaf stage of the respective host were inoculated with viruliferous whiteflies (*B. tabaci*) after 12h acquisition access period (AAP) feeding on yellow mosaic virus infected horsegram plant. Later the viruliferous whiteflies were allowed to feed on healthy test seedlings for 12 hr (IAP) in insect proof tubes. The inoculated seedlings were kept in insect proof glasshouse for development of symptoms. Observations were recorded on symptoms expression and per cent transmission.

Crop plants selected for host range are Green gram (*Vigna radiata*), Black gram (*Vigna mungo*), Piegonpea (*Cajanus cajana*), Soyabean (*Glycin max*) and Cowpea (*Vigna ungiculata*), Pea (*Pisum sativum*), French bean (*Phaseolus vulgaris*), Moth bean (*Vigna acontifolia*), Lima bean (*Phaseolus lunatus*), Field bean (*Vica faba*) and Lab lab bean (*Lablab purpureus*).

Weed hosts selected for the host range are *Acalypha indica, Malvastrunm coromandelium, Croton bonplandianum, Parthenium hysterophorus* and *Alternethera sessile.*

Results and Discussion

Disease incidence and symptoms

The roving survey was carried out to know the disease incidence of YMD during *Rabi* 2018 in major horsegram growing areas of North Eastern Karnataka *viz.*, Koppal, Raichur and Ballari by using disease rating scale 0 to 5. The observation was recorded on surrounding alternate weed hosts and cultivated crops from the respective location.

During the survey, natural symptoms of YMD on horsegram was characterised with irregular faint yellow specks on young trifoliate leaves. In addition, mild to severe mosaic signs with distorted and reduced leaf size were found. The diseased plant was very much stunted with complete cholorosis.

Incidence of YMD in Raichur district

Survey results revealed that, in Raichur taluk, the highest disease incidence of 18 per cent was observed in Galag village followed by Kaydigera and Alkod villages with 13 and 12.3 per cent respectively. The lowest disease incidence of 10.30 per cent was observed in Huched village (Table. 1)

The maximum disease incidence (46 %) was recorded in Mudgal village of Lingasugur taluk followed by 42 and 40 per cent in Mettur and Gudhihal villages respectively. Lowest disease incidence of 12.5 per cent was recorded in Anehosuru.

In Maski taluk, the highest disease incidence was found in Santhekalluru village with 30 per cent and lowest disease incidence of 23.00 per cent in Maski. While in Manvi taluk, 28.00 per cent disease incidence was found in Kotekal village.

Grand mean incidence of YMD in Raichur district varied from 10.68 to 33.50 per cent (Table. 2). Further the disease situation of YMD on horsegram from the selected taluks of Raichur district is represented in GPS maps.

During the survey, different kind of weed host viz., *Croton* sp., *Euphorbia* sp, *Acalypha sp., Malvastrum* sp. and *Parthenium sp.,* were

noticed in the adjacent locations. In addition to this, symptoms similar to YMD were also more prominent in crops like pigeon pea and several weeds such as *Croton* sp, *Euphorbia* sp, and *Malvastrum* sp. Further, in the surrounding surveyed areas, crops like cotton, brinjal and chilli were observed in majority locations of Raichur district.

Incidence of YMD in Koppal district

The highest disease incidence of 42 per cent was recorded in Basapur village of Koppal taluk followed by Ginigera with 40 per cent. Lowest disease incidence of 36 per cent was observed in Halagere village.

In Yalburga taluk, the highest disease incidence was noticed in Bandri with 42 per cent and lowest disease incidence of 32 per cent was observed in Adooru.

In Kushtagi taluk, the maximum disease incidence of 55 per cent was recorded in Bewoor, which was followed by Hireraralli and Shakappur villages with 52 and 45 per cent respectively. The minimum incidence of 35 per cent was recorded in Tavaregere.

In Gangavathi taluk, Budagumpa village recorded highest disease incidence of 45 per cent which is followed by Temba (42 %) and Halekunta (40 %). The least disease incidence of 28 per cent was noticed in Waddarahatti.

The mean incidence of YMD in Koppal district range from 37.25 to 44.91 per cent with grand mean disease incidence of 39.81 per cent (Table. 2). Further the disease status of YMD on horsegram from the selected taluks of Koppal district is represented in GPS maps.

In Koppal district, it was found that *Croton* sp., *Euphorbia* sp., *Acalypha sp.*, *Malvastrum* sp., *Alternenthera sp.* and *Parthenium sp* with characteristic symptoms of YMD were more prominent in different surveyed locations. Gourd crops, chilli, brinjal and pigeon pea crops were more predominant in surrounding areas of the crop survey.

Incidence of YMD in Ballari district

Incidence of YMD in Ballari taluk indicated, the maximum of 52 per cent was recorded in Yelubenchi, followed by Hagari (46 %) and Haraginadoni (44 %). The least disease incidence of 32 per cent was observed in Kuditini.

In Hospet taluk, the maximum disease incidence 40 per cent was observed in Papinayakanahalli, which is followed by Chilakanahatti and Mariyammanahalli with 36 and 32.00 per cent respectively. The least disease incidence of 28 per cent was seen in Kunikera.

Gudekote village recorded the highest disease incidence of 32 per cent in Kudligi taluk, while least incidence (28 %) found in Hansi.

Chintrapalli village of Hagari bommanahalli taluk registered maximum disease incidence of 29.5 per cent followed by Hampasagara with 27 per cent. Lowest disease incidence of 22.5 per cent was observed in Kodlabalu village.

At Huvina Hadagali taluk, the highest disease incidence of YMD was recorded in Komaranahalli (32 %) followed by Holegundi and Hyarada with 31.5 and 31 per cent respectively. Lowest disease incidence of 28 per cent was recorded in Bennihalli.

The mean incidence of YMD on horsegram in Ballari district varied from 26.75 to 43 per cent with grand mean disease incidence of 32.87 per cent (Table. 2). The disease prominence of YMD on horsegram from the

selected taluks of Ballari district is represented in GPS maps.

During the survey, observations made on surrounding cultivated crops and weed hosts in the respective locations. From the results, different kind of weed hosts such as *Croton bonplandianum, Euphorbia geniculata, Phyllanthus madraspatensis, Malvastrunm coromandelium, Acalypha indica* and *Alternenthera sessile* with symptoms of vein clearing and light to dark patches of yellow mosaic disease was observed.

Among three districts surveyed the highest grand mean incidence of 39.81 per cent was recorded in Koppal district followed by Ballari and Raichur with 32.87 and 24.67 per cent respectively. Further, the survey also revealed that the incidence was prevailed at all stages of the crop and present in all horsegram growing areas of North Eastern Karnataka. Disease scenario of YMD on horsegram from the selected districts of North Eastern Karnataka is represented in GPS maps (Fig. 1).

The present investigations on YMD survey in major horsegram growing areas of North Eastern Karnataka revealed that the highest incidence of YMD was found in Bewoor (55%) village of Kustagi taluk followed by Bodugumpa village of Gangavati taluk (45 %). While least incidence was noriced in Waddarahatti (28 %) of Gangavati taluk. In Raichur district, mudugal village of Lingasugur taluk has recorded 46 per cent followed by Mettur village (42 %). The lowest incidence was recorded in Huched village of Raichur taluk (10.30 %). The highest incidence of YMD in Horsegram was found in Yelubenchi village of Ballari taluk (52 %) followed by Hagari (46 %) and least was noticed in Kodlabalu of HB halli taluk (22.5 %) (Fig. 2).

Highest incidence of yellow mosaic virus disease on horsegram in selected villages of Koppal and Ballari district might be attributed to the presence of abundant cultivated crops *viz.,* Pigeon pea and gourd crops and weed hosts such as *Croton bonplandianum, Euphorbia geniculata, Phyllanthus madraspatensis, Malvastrunm coromandelium, Acalypha indica* and *Alternenthera sessile* which may served as alternate source of virus inoculums. Further, several surrounding crops such as cotton, chilli, brinjal and gourd crops also found in the major surveyed locations found to be source of whitefly in dissemination of virus inoculum.

Similarly, Deepa *et al.,* (2017a) reported that the highest disease incidence of YMD on Greengram with 76.70 per cent was recorded in Koppal followed by Bidar, Yadgir, Kalburgi with 70.48, 66.70 and 54.51 per cent respectively. Lowest disease incidence of 51.49 per cent was noticed in Raichur district. The high magnitude of YMD on greengram attributed to cultivation of local susceptible greengram variety (Chinamung) and poor awareness of plant protection measures by farmers. The high incidences were influenced by the sources of virus inoculum on leguminous crops such as soybean, pigeon pea and volunteer greengram crops besides potential off season weed hosts such as *Alternenthera sessile, Acalypha indica, Croton bonplandianum* and *Malvastrum coromandelianum* are implicated as the reasons for increased occurrence.

Further, higher yellow mosaic incidence on horsegram in North Eastern Karnataka districts could also be accredited to higher temperature and dry climate prevailing in these districts which may had directly influenced the vector population and its migration behavior. In this connection Meghashree *et al.,* (2017) revealed that the

maximum temperature had positive significant correlation with whitefly population and MYMV disease incidence has correlation with maximum relative humidity and maximum temperature and which intern indicates that higher the maximum temperature more is whitefly population and increase in relative humidity increase in disease. In addition to this, YMD incidence differs from location to location based on the cropping pattern and weather patterns. Further, several studies revealed that the population of whitefly and incidence of tomato leaf curl disease was high in August to October wherein rainfall will be very less with dry weather (Board *et al., 1*993). Similarly in case of cotton, leaf curl virus, whitefly was found positively correlated with maximum temperature and relative humidity and negatively correlated with rainfall (Kadam *et al.,* 2015). There was a similar finding noticed by Abhishek, *et al.,* (2016), who confirmed the higher incidence of tomato leaf curl disease during October due to higher whitefly population.

Host range studies

The HYMV is preferably infect horsegram and it produces symptoms like yellow discoloration on the leaves that leads to irregular, small, greenish yellow mosaic. The present investigation to identify the natural hosts of HYMV, different host plants belongs to family leguminaceae and several weeds were tested by artificial inoculation using viruliferous whiteflies.

The results unveiled that the causal virus of the disease was successfully transmitted from infected horsegram to different host plants *viz.,* Blackgram (*Vigna mungo*), greengram (*V. radiata*), Soybean (*Glycine max*), and Pigeon pea (*Cajanus cajana*) (Table.9). Further, in weeds like *Croton bonplandianum*, *Parthenium hysterophorus, Malvestrunm coromandelium* and *Alternenthera sessile* were also recorded successful transmission of HYMV under artificial inoculation. HYMV was unable to transmit to pea, mothbean and lima bean.

Symptomatology of *Horsegram yellow mosaic virus* on inoculated crop plants

Blackgram (*Vigna mungo*)

The initial symptoms of leaf puckering and mosaic appears on growing trifoliate leaves were observed after 18-22 days of inoculation with 30 per cent transmission. Final symptoms were of severe distorted leaves and stunted growth of plants was observed at 29-32 days after inoculation.

Soybean (*Glycine max*)

The typical symptoms were noticed 20-22 days after inoculation on newly emerging leaves with dark mosaic appears on growing trifoliate leaves, leaf puckering, mosaic and distortion with 40 per cent transmission. Final symptoms of severe reduction in the leaf size and stunting of plants were observed after 30-34 days of inoculation.

Pigeon pea (*Cajanus cajana*)

Forty per cent transmission in 19-24 days after inoculation was noticed with typical symptoms of vein clearing, small yellow patches on trifoliate leaves which later turn to dark yellow mosaic. Finally leaves become sever chlorosis in 35-40 days after inoculation.

Greengram (*Vigna radiata*)

The characteristic symptoms were observed in 18-20 days after inoculation with 50 per cent transmission. The initial symptoms such as vein clearing followed by light mosaic were recorded. In 32-34 days of incubation, final symptoms were obtained with severe yellowing and distorted leaves.

Table.1 Incidence of yellow mosaic disease of horsegram in North Eastern parts of Karnataka during *rabi* 2018-19

District	Taluk	Village	Age of the crop (days)	Disease incidence (%)	Surrounding crop/weeds observed
Raichur	Raichur	Alkod	38	12.30	Pigeonpea, Cotton and *Croton* sp.
		Galag	38	18.00	Cotton, Pigeonpea, *Euphorbia* sp
		Huched	33	10.30	Cotton, *Euphorbia* sp., *Acalypha sp.*
		Kyadigera	31	13.00	Cotton, Pegionpea, *Euphorbia* sp.
		Yellamanna halla	38	10.50	Pigeonpea, Chilli, Cotton, *Croton* sp.
		Chandrabanda	35	00.00	Cotton and *Croton* sp.
	Lingasuguru	Kadarihal tanda	45	26.50	Pigeonpea, Chilli and *Croton* sp.
		Eachanahal	45	30.00	Pigeonpea, Ridge gourd, *Croton* sp.
		Anehosuru	42	12.50	Cotton, Pigeonpea, *Euphorbia* sp.
		Mudgal	48	46.00	*Malvestrum* sp., *Acalypha sp.*,Cotton, *croton* sp.
		Mettur	50	42.00	*Acalypha sp.*,Cowpea.
		Gudihal	46	40.00	Cotton, Pigeonpea, *Euphorbia* sp.
		Toralabenchi	40	36.00	*Euphorbia* sp., *Acalypha sp.*
		Basapur	42	35.00	*Malvastrum* sp., *Acalypha sp.*
	Maski	Maski local	38	23.00	Cotton, Pigeonpea, *Euphorbia* sp.
		Santhekalluru	40	30.00	*Euphorbia* sp., *Acalypha sp.*
	Manvi	Kotekal	45	28.00	Cotton, Pigeonpea, *Euphorbia* sp.
Koppal	Koppal	Ginigera	45	40.00	*Croton* sp., *Malvastrum* sp., Gourd crops
		Basapur	42	42.00	*Malvastrum* sp., *Acalypha sp.*, Sunflower.
		Kunikera	40	40.00	*Euphorbia* sp., *Acalypha sp.*,Brinjal and Vegetables
		Hyati	41	39.00	*Croton* sp., *Malvastrum* sp., Gourd crops
		Halagere	40	36.00	*Acalypa sp.*, *Malvastrum sp.*, black gram
		Bhanapura	42	37.50	*Malvastrum* sp., *Acalypha sp.*
	Yelburga	Adooru	40	32.00	*Croton* sp., *Malvastrum* sp., Gourd crops
		Kukanooru	45	40.00	*Malvestrum* sp., *Acalypha sp.*,
		Bandri	42	42.00	*Euphorbia* sp., *Croton* sp., Pigeonpea
	Kushtagi	Hireraralli	45	52.00	*Croton* sp., *Malvastrum* sp., Gourd crops
		Bewooru	48	55.00	*Croton* sp., *Malvastrum* sp., Gourd crops

District	Taluk	Village	Age of the crop (days)	Disease incidence (%)	Surrounding crop/weeds observed
		Shakappur	45	45.00	*Croton* sp., *Malvastrum* sp., Gourd crops
		Kandakuru	45	42.00	*Acalypha sp.*, *Croton* sp., Pigeonpea
		Tavaregere	43	35.00	*Malvastrum* sp., *Croton* sp., Pigeonpea
	Gangavathi	Basavapattana	42	35.00	*Malvastrum* sp., *Acalypha sp.*
		H Benkal	42	32.00	*Euphorbia* sp., *Croton* sp.,
		Budagumpa	40	45.00	*Alternenthera.*, *Acalypha* sp., cowpea, cotton
		Laximipur	41	40.00	*Euphorbia* sp., *Croton* sp., Chilli, cotton
		Temba	45	42.00	*Malvestrum* sp., *Acalypha sp.*, Pigeonpea
		Halekunta	42	40.00	*Alternenthera.*, Pigeonpea and Gourd crops
		Toralabenchi	42	36.00	*Euphorbia* sp., *Croton* sp., Gourd crops
		Waddarahatti	40	28.00	*Malvestrum* sp., *Acalypha sp.*, Cowpea
Ballari	Ballari	Hagari	38	46.00	Cotton, Pigeonpea , *Euphorbia* sp.
		Kudutini	40	32.00	*Malvastrum* sp., *Acalypha sp.*
		Haraginadoni	41	44.00	*Euphorbia* sp., *Croton* sp., Pigeonpea
		Yelubenchi	42	52.00	*Malvastrum* sp., *Acalypha sp.*
	Hospet	Mariyammanahalli	40	32.00	*Euphorbia* sp., *Croton* sp., Cowpea
		Chilakanahatti	40	36.00	*Alternenthera.*, *Croton* sp., Chilli
		Papinayakanahalli	41	40.00	*Alternenthera.*, *Croton* sp., Pigeonpea
		Kunikera	42	28.00	*Euphorbia* sp., *Croton* sp., Cowpea
	Kudligi	Kudligi	42	28.50	*Malvastrum* sp., *Croton* sp., Chilli
		Gudekote	41	32.00	*Alternenthera.*, *Croton* sp., Pigeonpea
		Ichanala bommanahalli	41	30.00	*Euphorbia* sp., *Croton* sp., *Alternenthera*
		Hansi	41	28.00	*Euphorbia* sp., *Croton* sp., Cowpea
	Hagari bommanahalli	Chintrapalli	42	29.50	*Malvastrum* sp., Pegion pea
		Kodlabalu	43	22.50	*Euphorbia* sp., *Croton* sp.
		Hampasagara	42	27.00	Alternenthera., Pegion pea
	Huvina Hadagali	Bennihalli	40	28.00	*Malvastrum* sp., *Alternenthera*
		Holalu	39	29.50	*Euphorbia* sp., *Croton* sp., *Alternenthera*
		Hyarada	40	31.00	*Malvastrum* sp., Sunflower, Gourd crops
		Holegundi	43	31.50	*Malvastrum* sp., Alternenthera, Gourd crops
		Komaranahalli	40	32.00	*Euphorbia* sp., *Croton* sp., Gourd crops

Table.2 Average incidence of yellow mosaic disease on horsegram in different districts of North Eastern Karnataka during *rabi* 2018-19

District	Taluk	Average disease incidence (%)	Grand mean incidence (%)
Raichur	Raichur	10.68	24.67
	Manvi	28.00	
	Maski	26.50	
	Lingsugur	33.50	
Koppal	Koppal	39.08	39.81
	Yelburga	38.00	
	Kushtagi	44.91	
	Gangavathi	37.25	
Ballari	Ballari	43.00	32.87
	Kudligi	29.62	
	Hadagali	31.00	
	Hagari bommanahalli	26.75	
	Hospet	34.00	

Table.3 Host range of *Horsegram yellow mosaic virus* on different crops

Sl. No	Crop	Family	Total No. of plants tested	Total No. of plants infected	Per cent transmission	Days to first symptom appearance	Days to final symptom appearance	Early symptom appearance	Final symptom appearance
1	Blackgram (*Vigna mungo*)	Leguminaceae	10	3	30.00	18-22	29-32	Leaf puckering, mosaic and distorted leaves	Severe distorted leaves and plants become stunted
2	Soybean (*Glycine max*)		10	4	40.00	20-22	30-34	Light green mosaic appears on growing trifoliate leaves	Leaves become dark green mosaic with deformation and leathery apperence
3	Pigeon pea *(Cajanus cajana)*		10	4	40.00	19-24	35-40	Vein clearing followed by light mosaic	Leaves become sever yellowing and distorted
4	Green gram (*Vigna radiata*)		10	5	50.00	18-20	32-34	Vein clearing followed by light mosaic	Leaves become yellowing and distorted
5	Pea (*Pisum sativum*)		10	0	0.00	-	-	Nil	Nil
6	Moth bean (*Vigna acontifolia*)		10	0	0.00	-	-	Nil	Nil
7	Lima bean (*Phaseolus lunatus*)		10	0	0.00	-	-	Nil	Nil

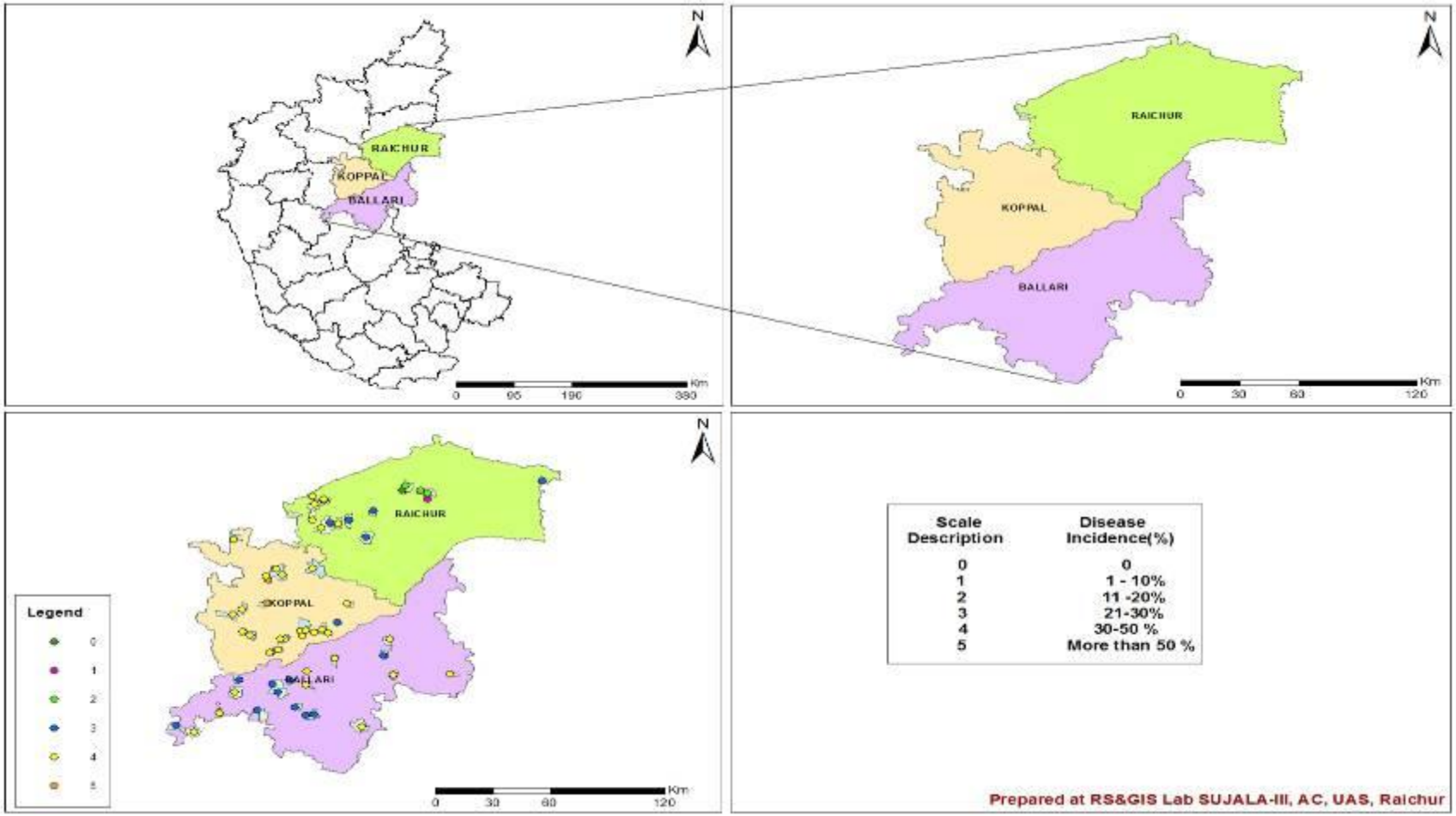
Note: No. of whiteflies/seedlings: 10, Culture: MYMV, AAP: 12 h, IAP: 12h, Nil: No symptom expression

Table.10 Host range of *Horsegram yellow mosaic virus* on different weed hosts

Sl. No.	Weeds	Family	Total No. of plants tested	Total No. of plants infected	Per cent transmission	Days to first symptom	Days to final symptom	Early symptom appearance	Final symptom appearance
1	*Croton bonplandianum*	Euphorbiaceae	5	3	60.0	20-22	35-40	Vein clearing and light to dark patches of yellow mosaic	Complete yellowing, puckering and raised green areas.
2	*Euphorbia geniculata*		5	0	0.00	-	-	Nil	Nil
3	*Acalypha indica*		5	0	0.00	0	0	-	-
4	*Parthenium hysterophorus*	Asteraceae	5	2	40.00	20-24	38-41	Mild leaf curl, partial yellow mosaic	Complete yellowing
5	*Ageratum conyzoides*		5	0	0.00	-	-	Nil	Nil
6	*Phylanthus niruri*	Phyllanthaceae	5	0	0.00	-	-	Nil	Nil
7	*Alternenthera sessile*	Amaranthaceae	5	4	80.00	21-22	39-41	Vein clearing on trifoliate leaves with light mosaic	Complete dark yellowing of leaves
8	*Malvastrum coromandelianum*	Malvaceae	5	3	60.00	18-20	35-40	Vein clearing and small yellow patches	Complete yellowing of leaves

Note: No. of whiteflies/seedlings: 10, Culture: HYMV, AAP: 12 h, IAP: 12h, Nil: No symptom expression.

Fig. 1 GIS map showing spatial variation of YMD on horsegram in selected districts of North Eastern Karnataka during *rabi* 2018-19




Disease incidence (%)
Per cent disease incidence
50
45
40
35
30
25
20
15
10
5
0
10.68
28
26.5
33.5
39.08
38
44.91
37.25
43
29.62
31
26.75
34
Raichur
Manvi
Maski
Lingasuguru
Koppal
Yelburga
Kushtagi
Gangavathi
Ballari
Kudligi
Hadagali
HB Halli
Hospet
Taluks

Severe outbreak of yellow mosaic disease on horsegram in north eastern Karnataka during rabi 2019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Croton sp. Showing systemic infection upon inoculated with Horsegram yellow mosaic virus

Greengram expressing mosaic like symptoms

Symptomatology of HYMV on inoculated weed hosts

Croton bonplandianum

Sixty per cent transmission was obtained with initial symptoms of vein clearing and light to dark patches of yellow mosaic symptoms at 20-22 days after inoculation.

Final symptoms of complete yellowing and leaf puckering signs were observed at 35-40 days after inoculation.

Parthenium hysterophorus

The initial symptoms were observed on plants at 20-24 days after inoculation with 40 per cent transmission. The infected plants exhibited mild leaf curling and partial yellow mosaic. The final symptoms of complete yellowing was noticed at 38-41 days after inoculation.

Alternenthera sessile

The symptoms of vein clearing on trifoliate leaves with light mosaic were observed after 21-22 days of inoculation with 80 per cent transmission. The infected plants exhibited final symptoms of sever leaf yellowing and distortion at 39-41 days after inoculation.

Malvastrum coromandelianum

Sixty per cent transmission with typical symptoms was noticed at 18-20 days after inoculation. On newly emerging leaves, vein clearing and small yellow patches appeared on trifoliate leaves. Finally yellowing with distorted and malformed leaves was noticed at 35-40 days after inoculation.

The present findings are in confirmatory with the host range studies of most of the yellow mosaic viruses of legume is restricted to Leguminaceae or Fabaceae species (Nene *et al.*, 1971 and Rathi and Nene, 1974). Further, Muniyappa *et al.,* (1987) who successfully transmitted HYMV to 11 leguminous species *viz., Cajanus cajan, Centrosema* sp., *Phaseolus acontifolius, P. atropurpureus, P. lathyroides, P. lunatus, P. vulgaris, Vigna radiata, G. max, Vigna mungo* and *Teramnus uncinatus* which shown yellow mosaic symptoms. Further, MYMIV infect several leguminous species like blackgram, cowpea (*V. unguiculata*), French bean (*P. vulgaris*), mungbean and soybean (*G. max*) (Varma *et al.,* 1992).

The above results are found similar with the investigations on host range of *Mung bean yellow vein mosaic virus* (Deepa *et al.,* 2017). The virus was limited to only few plant and weed species *viz.,* Tobacco (*Nicotiana benthamiana*), Blackgram (*Vigna mungo*), Cowpea (*V ungiculata*), Horsegram (*Macrotyloma uniflorum*), Pigeon pea (*Cajanus cajana*), Soybean (*Glycine max*), *Acalypa indica, Alternenthera sessile, Croton bonplandianum, Euphorbia geniculata* and *Malvestrunm coromandelium,* with varied transmission rates.

The comprehensive research towards the identification of source and perpetuation of HYMV, seven plant species and eight dicotyledonary weed hosts were inoculated with HYMV isolate from horsegram. Among the seven crop plants examined, HYMV was able to cause mosaic symptoms on Blackgram (*Vigna mungo*), greengram (*V. radiata*), Soybean (*Glycine max*) and Pigeon pea (*Cajanus cajana*). Among eight weed species tested, HYMV was able to cause infection on *Croton bonplandianum, Parthenium hysterophorus, Malvestrunm coromandelium* and *Alternenthera sessile* with characteristic symptoms like vein clearing, leaf curling, irregular small yellow patches and complete yellowing were observed. Further there was a

difference in transmission rates and expression of virus symptoms between crops and weeds. This could be due to *B. tabaci* preference and also host biochemical compositions which may interfere with virus multiplications (Pramesh *et al.,* 2013). Further the transmission efficacy on different hosts depends on the age of the seedlings. When the age of the seedlings increases the per cent transmission going to decrease and also severity will be more at early stages of the host (Jayappa *et al.,* 2017). In addition, virus-induced biochemical and physiological changes in the host-plant have been shown to influence vector insect host preference (Mauck *et al.,* 2014).

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