A-6252
[1-8]

RESEARCH ARTICLE Indian Journal of Agricultural Research, Volume Issue : ()

Relationship between Whiteflies, Yellow Mosaic Severity, Weather and Crop Age in Soybean

Sunil Kumar[1], Pawan K. Amrate[2], M.K. Shrivastava[2], R.S. Marabi[3], Shivani Jawarkar[2], Sanjay Kharte[1], Kailash Chaukikar[3], Akash Barela[2]

10.18805/IJARe.A-6252

ABSTRACT

Background: Yellow mosaic disease (YMD), caused by the Mungbean yellow mosaic India virus (MYMIV), seriously affects soybean production in the central and northern regions of India.

Methods: The present investigation was conducted to reveal the relation among the fluctuating population of whiteflies, YMD progression, meteorological parameters and crop age in four varieties, *i.e.* 335, JS 20-34, NRC 86 and MACS 1520, at J.N.K.V.V., Jabalpur, during *kharif 2021* (June to September). The whitefly population, by visual and cage and YMD severity were recorded at weekly intervals.

Result: Whiteflies first appeared 13 days after sowing (27th SMW) and reached a peak of 7.73 per plant (cage) and 3.29 per trifoliate (visual) at 29th SMW (July, 16-22). During this maximum and minimum temperature, morning and evening RH were 33.4 and 25.4°C, 84.10 and 70.0 %, respectively. Whiteflies on JS 335 (0.639* and 0.635*) and MACS 1520 (0.672* and 0.639*) significantly positively correlated with maximum temperature in visual and cage counts. Wind speed exhibited a significant negative relation with a whitefly count of JS 335 (-0.753*) and MACS 1520 (-0.764*). YMD initiated (28th SMW) at high temperature (max 33.3°C and min 25.1°C), low rainfall (33.2 mm), less humid conditions (evening 58.3-morning 85.1 %) and presence of whitefly. In contrast, at the time of maximum disease progression (32nd SMW), comparative low temperature (max 28.5 and min 24.2°C) and high humid conditions (evening 79.0-morning 90.0) prevailed. Among the four varieties, maximum disease severity was recorded in JS 20-34 (48.16%). The corresponding week's maximum temp (0.771**) and sunshine hours (0.792**) were negatively significant and evening RH (0.717*) and wind speed (0.708*) had a positively significant relation with mean YMD progression. A similar significant association was also obtained between the previous week's parameters and disease. YMD and whitefly exhibited a negative, non-significant association. Crop age also linked non-significantly with YMD progression. The present findings could be utilized to predict vector and YMD and to formulate appropriate management strategies for both.

Key words: Crop age, Progression, Soybean, Weather, Whitefly, Yellow mosaic disease (YMD).

INTRODUCTION

Soybean [*Glycine* max (L.) Merrill] (2n=40) regarded as "wonder crop", "golden bean", "Miracle bean", "protein hope of the future", "Super legume" and "Golden Nugget" is the richest, cheapest and most accessible source of best quality proteins, fats and fibres (Liu, 2000; Upadhyay *et al.*, 2020; Barela *et al*., 2022; Ramlal *et al*., 2023; Jawarkar *et al*., 2023). It is one of the richest vegetarian sources of total proteins (36.1-42.8%); additionally, it contains considerable edible oil (16.8-20.2%) and several vitamins, minerals, essential fatty acids, omega-3 fatty acids and antioxidants, thereby utilizing for several purposes, like food and feed for human and animals, pharmaceutical and industrial *etc* (Kumar *et al.,* 2020; Uikey *et al.,* 2022; Banerjee *et al*., 2023; Amrate *et al.,* 2024). Its consumption reduces the risk of developing cancer, heart attack and cholesterol and triglyceride levels in the human body (Parle *et al.,* 2014; Banerjee *et al.,* 2022). In India, it is grown over an area of 12.7 Mh with production of 10.45 MT and productivity of 0.82 tons per hectare as per the data of 2020-21 (USDA, 2022). However, India is among the top five nations regarding soybean cultivation in the world, but production, productivity and area has fluctuated since 2012-13 (Sagarika *et al.,* 2023; Amrate *et al.,* 2024).

Soybean is the preferred host for most kinds of fungi, bacteria, nematodes and viruses and about 135 pathogens

[1]Department of Plant Pathology, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur-482 004, Madhya Pradesh, India.
[2]Department of Plant Breeding and Genetics, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur-482 004, Madhya Pradesh, India.
[3]Department of Entomology, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur-482 004, Madhya Pradesh, India.

Corresponding Author: Pawan K. Amrate, Department of Plant Breeding and Genetics, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur-482 004,Madhya Pradesh, India.
Email: pawanamrate@gmail.com

How to cite this article: Kumar, S., Amrate, P.K., Shrivastava, M.K., Marabi, R.S., Jawarkar, S., Kharte, S., Chaukikar, K. and Barela, A. (2024). Relationship between Whiteflies, Yellow Mosaic Severity, Weather and Crop Age in Soybean. Indian Journal of Agricultural Research. doi: 10.18805/IJARe.A-6252.

Submitted: 08-05-2024 **Accepted:** 23-07-2024 **Online:** 13-08-2024

have been observed infecting soybean throughout the world (Hartman and Hill, 2010). Among these,>50 viruses have been observed affecting soybean crops (Nyvall, 1989). In India, soybean crop is grown in the *kharif* season under rainfed conditions wherein severe attacks of many diseases have been reported (Rajput *et al.,* 2021; Amrate *et al*., 2023a; Amrate *et al*. 2023b; Amrate *et al.,* 2024).

There are fourteen disease which infect soybean crop at different growth stage in central Indian conditions (Amrate *et al.*, 2021; Amrate, 2024). Among all the diseases, yellow mosaic is a major one distributed in India, Srilanka, Bangladesh, Pakistan and Thailand (Kumar *et al.,* 2022). During the early 1970s, YMD was observed in the northern plains of India. It gradually started appearing in central India and has become a common disease of soybean, mungbean and urdbean (Amrate *et al*., 2023a). In Central India, yellow mosaic disease in soybean is caused by Mungbean yellow mosaic India virus (MYMIV) and exclusively transmitted by whitefly (*Bemisia tabaci* Genn.) in a persistent manner (Talukdar *et al*., 2013; Kumar *et al*., 2014; Amrate *et al*. 2023a). Yellow mosaic is a common disease that infects soybean varieties and many genotypes yearly in central and northern Indian conditions (Amrate *et al*., 2018; Singh and Aravind, 2019; Kumar *et al.,* 2022; Amrate *et al.,* 2023a). Its vector, the whitefly, sucks the phloem sap from the lower surface of leaves and requires a temperature higher than 26°C and 60% relative humidity for optimum development (Nene, 1972; Butler *et al.,* 1983). A single viruliferous whitefly can able to transmit virus (Swathi *et al.,* 2023). Mungbean yellow mosaic virus-affected plant exhibits irregular and varying size contrast yellow-green patterns (mottels) on leaves (Silodia *et al*. 2018; Amrate *et al*., 2020a; Kumar *et al.,* 2022). YMD quickly spreads during the early stage of soybean growth, resulting in the alteration of biochemical and yield-attributing traits and severe yield reduction of up to 85.7% in soybeans (Amrate *et al.,* 2020b; Kumar *et al.,* 2022). In India, annual yield losses caused by YMD in soybean, black gram and green gram have been recorded at about 300 million USD per year (Varma and Malathi, 2013). It has been noticed that disease incidence and severity of YMD in soybean varied year to year depending upon vector population and weather conditions. Considering the significance of yellow mosaic disease in soybean cultivation, the present investigations were undertaken to establish a relation between the development of yellow mosaic of soybean with vector and meteorological parameters.

MATERIALS AND METHODS

Experimental details

A field experiment was undertaken to record the influence of prevailing weather and vector (Whitefly) on yellow mosaic disease severity in soybean during *kharif*, June to September 2021, at the experimental field of AICRP on Soybean at J.N.K.V.V., Jabalpur (latitude 23°12'42″N and longitude 79°56'53″E). Four yellow mosaic susceptible varieties, *i.e.* JS 20-34, JS 335, NRC 86 and MACS 1520, were sown on 25th June 2021 in three replications. Sowing was done in a well-drained sandy, loamy soil. Each variety had been maintained in a plot size of 3.0×1.2 m^2 (3 rows of 3 m length). Initially, seeds were treated with thiophenate methyl 45%+pyraclostrobin 5% @ 1.5 ml/kg seed and sprayed with tebuconazole 25.9 EC @ 1.25 ml/litre at 45 days to avoid the attack of fungal disease in the experimental plot. Proper thinning was done ten days after sowing to maintain the

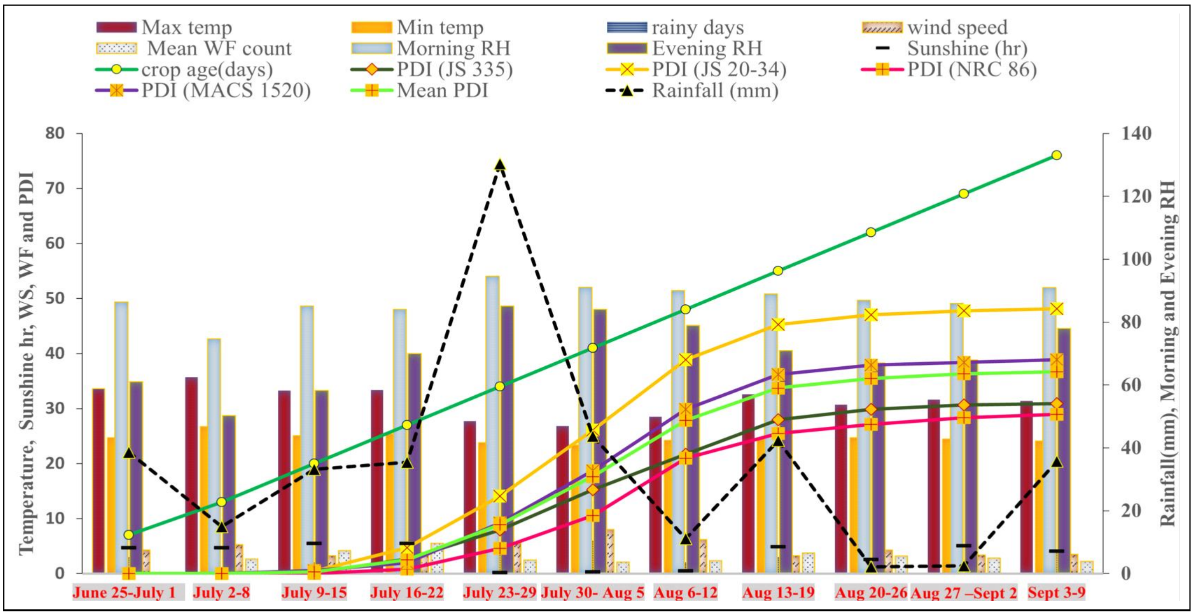

Fig 1: Weekly weather variables, Whitefly (WF) and progression of YMD (PDI) in soybean varieties during *Kharif* 2021 at Jabalpur.

plant-to-plant distance (7-8 cm) and the row-to-row distance was kept at 40cm. All packages and practices were applied to care for the crop except insecticides.

Recording of meteorological parameters

Meteorological variables at the experimental location during the cropping season, *viz.,* maximum and minimum temperature, morning and evening relative humidity, wind speed, sunshine hours, rainy days and rainfall, were collected from the Meteorological Observatory, Department of Physics and Agro-meteorology, College of Agricultural Engineering, J.N.K.V.V., Jabalpur (M.P) (Fig 1).

Monitoring of vector

Whitefly populations on all four varieties were monitored at weekly intervals by visual and cage methods.

By visual

Whitefly present on upper two trifoliate leaves were counted during morning hours (before 8:00 AM) by twisting of leaves (Bisht *et al.*, 2017; Amrate *et al*. 2023a) (Fig 2). Population of adult fly was recorded from five randomly selected plants.

By cage

The cage was designed with plastic cylinders of different heights and diameters (20×15, 40×25 and 60×45 cm). The inner wall of the cage was coated with black paint to induce darkness and one end was left open while the other was closed with transparent polythene. The cage was fixed so that no space was left to escape the adult whitefly from inside the cage. The adult whitefly population was recorded on five randomly selected plants with the help of a cage. To record the number of adult whitefly populations, the cage was carefully placed on an individual plant without disturbing it. The adult whitefly congregated on the inner surface of the polyethene due to its phototactic behaviour, which enabled it to count them easily (Fig 2). In the early stage of crop growth, narrow-diameter cages were used, while in the later stages, cages with broader diameters

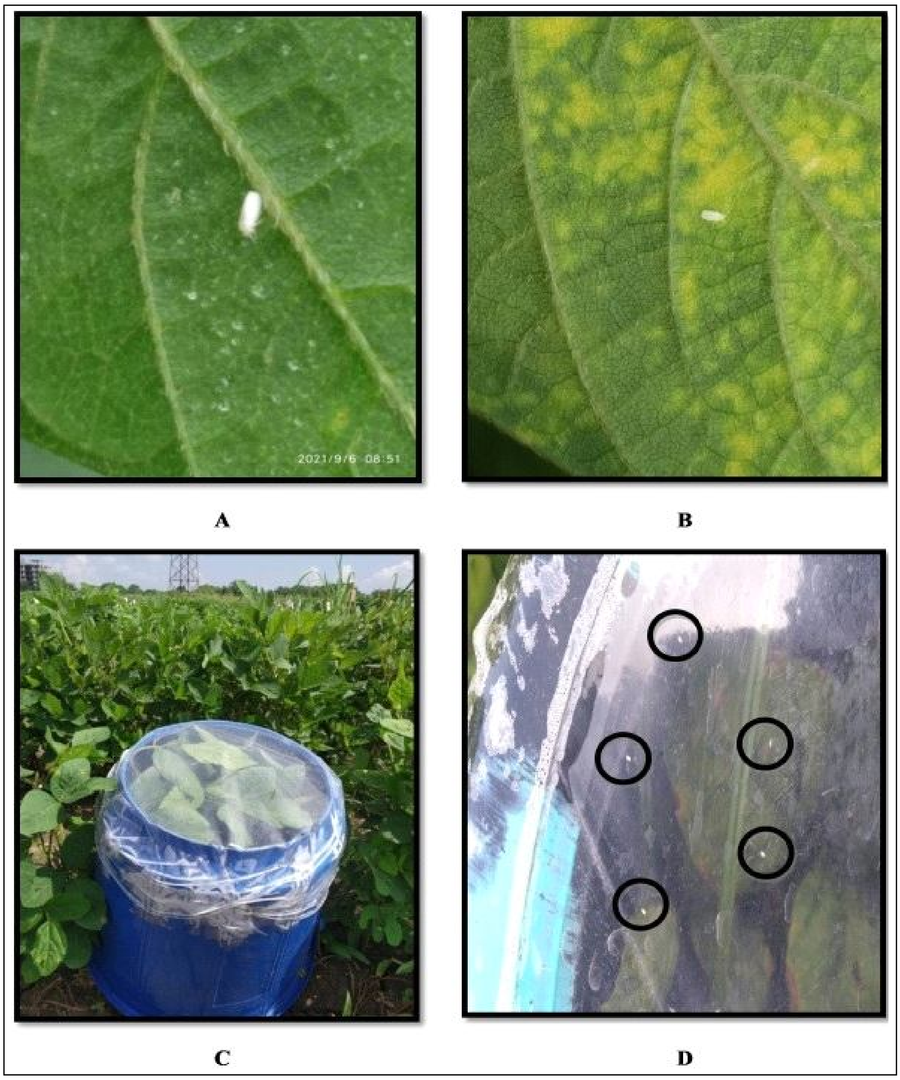

Fig 2: Counting of adult whitefly by visual (A+B) and Cage Method (C+D).

with more height and sufficient space to cover an individual plant were used for recording the observations (Marabi *et al.,* 2017a).

Recording of YMD intensity

Plants were observed critically for yellow mosaic development throughout the cropping season. Disease severity was recorded weekly per standard meteorological weeks from the vegetative stage (V1) to the reproductive stage (R6). The severity of the yellow mosaic was recorded on 20 randomly selected plants. From each plant, four leaves (two upper and two middle) were observed and each was rated on a 0-9 grade disease rating scale (Anonymous, 2019) (Table 1). Per cent disease index (PDI) for yellow mosaic using the above severity grade was calculated as per the formula suggested by Wheeler (1969).

$$\text{PDI} = \frac{\text{Sum of numerical rating}}{\text{No. of leaves observed} \times \text{Maximum disease rating}} \times 100$$

Calculation of correlation matrix

Pearson's correlation coefficient was calculated based on the current and previous week's weather, increasing whitefly count and YMD severity at the experimental site for each variety and varietal average. Online statistical tools and MS Excel were used for the calculation. Significance was determined at the 1 (p=0.01) and 5 (p=0.05) per cent levels of error.

RESULTS AND DISCUSSION

Whitefly and weather

The first occurrence of whitefly on soybean was detected 13 days after sowing, on the 27th SMW (standard meteorological week), which was July 8th, 2021 (Table 2). The Whitefly population was varied in four varieties (Table 2). The highest whitefly counts, 3.87 per trifoliate (visual) and 8.53 pe plant (cage), were recorded in NRC 86 at 29th SMW (July 16-22). Simultaneously, the highest whitefly counts, 2.80 per plant (visual) and 7.00 per plant (cage) were recorded in JS 335 at 29th SMW. The mean initial whitefly population was 1.80 per trifoliate (visual) and 3.50 per plant (cage) at 27th SMW, *i.e.* July 8th. After that, a sudden increase in the whitefly population was observed and attained its peak at 29th SMW (July 16-22), which was 3.29 per trifoliate (by visual) and 7.73 per plant (by cage). At the time of the peak of the whitefly, maximum and minimum temperatures were 33.4 and 25.4°C respectively, whereas sunshine, wind speed, rainfall, morning Rh and evening Rh were 5.5 hrs, 3.9 km/hr., 35.4 mm, 84.10 and 70.0, respectively (Fig 1). Whitefly remained active till the crop's maturity, but a sudden decline in the whitefly population was seen at the time of maturity. The dynamics of the whitefly were nearly uniform in all varieties. Present findings corroborate the findings of Raghuvanshi *et al.* (2014), Ahirwar *et al.* (2015) and Marabi *et al.* (2017a), as they also reported that the first appearance of whitefly on soybean ranged from 14-30 DAS (28th-33rd SMW) to till maturity. Previous workers also reported similar weather parameters during the peak of white flies in the present investigation (Raghuvanshi *et al*., 2014).

In Pearson correlation, maximum and minimum temperature and sunshine hours exhibited positive relation [r= 0.535, 0.497 and 0.582 (visual) and 0.541, 0.426 and 0.659* (cage), respectively] with mean whitefly population (Table 3). Among varieties, whitefly counts in JS 335 (0.639* and 0.635*) and MACS 1520 (0.672* and 0.639*) significantly correlated with maximum temperature in both visual and cage counts. A similar significant positive relation was exhibited between white flies and sunshine hours. While rainfall, morning and evening humidity, rainy days, wind speed and crop age exhibited negative non-significant correlation with the mean white fly count in a cage of both methods. However, Wind speed exhibited a significant negative relation with the white fly count in a cage of JS 335 (-0.753*) and MACS 1520 (-0.764*). Present findings conform with the findings of many researchers (Kalkal *et al*., 2015; Marabi *et al*., 2017a; Marabi *et al*., 2017b; Amrate *et al*., 2023a) about white fly, maximum temperature and sunshine hours. However, researchers also reported that max temp had a negative impact on the whitefly population (Sharma and Kumar, 2014). Rainfall negatively correlated with the whitefly population (Marabi *et al*., 2017a; Amrate *et al.,* 2023a).

Progression of YMD

Yellow mosaic disease (YMD) appeared on the 28th SMW (Fig 1). At initiation, yellow mosaic disease severity was very low (Fig 1). During this period, high temperature (max 33.3°C and min 25.1°C), low rainfall (33.2 mm), less humid (evening 58.3-morning 85.1 %) and high whitefly population [2.65 per trifoliate (visual) and 5.78 per plant (cage)] prevailed. After that, there was a sharp increase in the disease severity between the 30th and the 33rd SMW. Maximum weekly disease progression was noticed in 32th SMW (06/08/2021 to 12/08/2021). At the time of maximum disease progression, max temp and minimum temperature were 28.5 and 24.2°C, respectively, whereas sunshine hours, rainfall, morning RH and evening RH were 0.5 hrs, 11.1 mm, 90.0 and 79.0%, respectively. While the whitefly population was 1.70 per plant (visual) and 3.04 per plant observed (cage) and the mean whitefly population was 2.37 per plant (Table 2). After that, disease progression

Table 1: Scoring of yellow mosaic disease by using 0-9 disease rating scale.

0-9 Scale (Rating)	Disease severity
0	No symptoms on plant or leaf
1	Up to 1% leaf area covers by yellow mottles
3	1.1-10% leaf area covers by yellow mottles
5	10.1-25% leaf area covers by yellow mottles
7	25.1-50% leaf area covers by yellow mottles
9	>50% leaf area covers by yellow mottles

was slow and maximum mean severity (36.71%) was recorded at 36th SMW on 76 DAS. Among four varieties, maximum disease severity was recorded in JS 20-34 (48.16%), followed by MACS 1520 (38.86%), JS 335 (30.91%) and NRC 86 (28.92%) (Fig 1, Fig 3). Previous workers have also reported similar weather conditions for

Table 2: Population dynamics of whitefly on different varieties growing during *Kharif* 2021.

SMW	Duration of week	Whitefly per trifoliate (by visual)					Whitefly per plant (by cage)					Mean WF population
		JS 335	JS 20-34	NRC 86	MACS 1520	Mean	JS 335	JS 20-34	NRC 86	MACS 1520	Mean	
27	July 2-8	1.73	2.00	1.53	1.93	1.80	3.47	3.73	3.13	3.67	3.50	2.65
28	July 9-15	2.60	2.80	2.47	2.73	2.65	5.73	6.00	5.47	5.93	5.78	4.22
29	July 16-22	2.80	3.60	3.87	2.87	3.29	7.00	8.20	8.53	7.20	7.73	5.51
30	July 23-29	1.33	1.73	1.73	1.47	1.57	3.13	3.80	3.27	3.33	3.38	2.47
31	July 30- Aug 5	1.27	1.47	1.53	1.33	1.40	2.40	3.47	2.80	2.53	2.80	2.10
32	Aug 6-12	1.53	1.73	1.87	1.67	1.70	2.27	4.13	3.27	2.47	3.04	2.37
33	Aug 13-19	2.13	2.07	2.07	2.27	2.14	5.27	5.53	4.87	5.67	5.34	3.74
34	Aug 20-26	1.73	1.87	2.00	2.07	1.92	4.73	5.00	3.60	4.93	4.57	3.24
35	Aug 27-Sept 2	1.67	1.47	1.73	1.80	1.67	4.40	3.93	3.27	4.60	4.05	2.86
36	Sept 3-9	1.33	1.07	1.40	1.47	1.32	3.73	2.27	2.67	3.93	3.15	2.23

Table 3: Relation of weather parameters with whitefly population.

Weather parameters	WF population by visual				WF population by cage				Mean	
	JS 335	JS 20-34	NRC 86	MACS 1520	JS 335	JS 20-34	NRC 86	MACS 1520	By visual	By cage
Max temp	0.639*	0.487	0.342	0.672*	0.635*	0.391	0.437	0.639*	0.535	0.541
Min temp	0.546	0.518	0.314	0.591	0.445	0.382	0.371	0.445	0.497	0.426
Sunshine hours	0.709*	0.475	0.430	0.715*	0.788**	0.453	0.529	0.792**	0.582	0.659*
Rainfall	-0.191	-0.014	-0.036	-0.240	-0.149	-0.081	-0.007	-0.145	-0.107	-0.096
Mor. RH	-0.429	-0.397	-0.196	-0.466	-0.315	-0.262	-0.238	-0.309	-0.373	-0.291
Eve. RH	-0.528	-0.400	-0.175	-0.588	-0.448	-0.298	-0.238	-0.446	-0.415	-0.367
Rainy Days	-0.284	-0.128	-0.081	-0.379	-0.303	-0.189	-0.051	-0.304	-0.207	-0.214
Wind speed	-0.566	-0.296	-0.340	-0.601	-0.753*	-0.357	-0.412	-0.764*	-0.446	-0.585
Crop age	-0.440	-0.630	-0.365	-0.413	-0.146	-0.418	-0.397	-0.136	-0.483	-0.294

*: Significant at (p=0.05); **: Significant at (p=0.01) level, WF = Whitefly.

Fig 3: Experimental view exhibiting appearance of yellow mosaic during last week of July (V-3 to R-1 crop stage).

Table 4: Pearson correlation matrix between weekly YMD increase in soybean varieties and corresponding current and previous week weather, whitefly and crop age.

Weather parameters and others	Current week					Previous week				
	JS 335	JS 20-34	NRC 86	MACS 1520	Mean PDI Increase	JS 335	JS 20-34	NRC 86	MACS 1520	Mean PDI increase
Max temp	-0.718*	-0.789**	-0.699*	-0.782**	-0.771**	-0.743*	-0.692*	-0.829**	-0.748*	-0.763*
Min temp	-0.603	-0.613	-0.546	-0.623	-0.613	-0.571	-0.550	-0.692*	-0.586	-0.608
Sunshine hours	-0.702*	-0.811**	-0.736*	-0.813**	-0.792**	-0.716*	-0.630	-0.769**	-0.710*	-0.714*
Rainfall	0.375	0.389	0.092	0.337	0.315	0.575	0.628	0.442	0.572	0.575
Mor. RH	0.603	0.596	0.519	0.607	0.597	0.630	0.566	0.614	0.580	0.606
Eve. RH	0.706*	0.745*	0.620	0.710*	0.717*	0.826**	0.771**	0.843**	0.829**	0.831**
Rainy days	0.571	0.593	0.311	0.531	0.522	0.720*	0.810**	0.797**	0.806**	0.806**
Wind speed	0.632*	0.753*	0.623	0.718*	0.708*	0.627	0.634*	0.815**	0.727*	0.713*
Crop age	0.036	-0.055	0.135	0.018	0.024	0.036	-0.055	0.135	0.018	0.024
Mean WF population	-0.397	-0.101	-0.258	-0.567	-0.341	-0.397	-0.101	-0.258	-0.567	-0.340

* = Significant at (p=0.05); ** = Significant at (p=0.01) level.

the development and progression of YMD (Singh *et al*., 2009; Silodia *et al.,* 2018; Amrate *et al.,* 2023a). Amrate *et al.* (2023a) indicated that low mean temp and high rainfall in July (cool) lead to low white fly and low YMD and conversely, high mean temperature and low rainfall in July (hot) lead to high white fly and high diseases in the overall season.

Relation of YMD, weather, crop age and whitefly

Pearson correlation matrix between corresponding week's weather parameters, crop age and vector population with YMD severity revealed that max temp and sunshine hours (r = -0.771**and -0.792**, respectively) were significant negatively and evening RH and wind speed (r = 0.717* and 0.708*, respectively) were significant positively correlated with mean YMD progression (Table 4). A similar significant relation was exhibited in the case of all four varieties for a max temperature, sunshine hour, evening RH and wind speed. While rainfall, Morning RH, rainy days and crop age (r = 0.315, 0.597, 0.522 and 0.024, respectively) had a positive, non-significant relation with YMD progress. Meanwhile, in JS 20-34, crop age showed a negative correlation (r = -0.055) with disease progression. Meanwhile, minimum temp and mean vector population (r = -0.613 and -0.341, respectively) were negatively correlated with YMD progression.

Relation between disease progression and previous week parameters (*viz*., weather parameters, crop age and vector population) revealed that evening RH, rainy days and wind speed (r = 0.831**, 0.806** and 0.713*, respectively) had a significant positive correlation with disease severity (Table 4). Similar to the current week's pattern, max temp and sunshine hours (r = -0.763* and -0.714*, respectively) were negatively correlated with the progression of disease severity. While rainfall, morning RH and crop age had a positive and minimum temp, the mean vector population had a negative, non-significant relation with the disease. A similar pattern, as revealed with the current week's relation, was exhibited except on rainy days wherein disease progression in all the varieties and their mean were positively significantly related. Previously, Marabi *et al.* (2017b) reported that maximum temp and sunshine hours significantly positively impacted YMD incidence. Researchers also supported our findings regarding the negative association of YMD with rainfall and other parameters in blackgram and soybean (Marabi *et al.*, 2017b; Srivastava *et al.,* 2021). Amrate *et al*. (2023a) reported that the coefficient of infection of YMD was significantly correlated with the whitefly population.

CONCLUSION

It is concluded that the whitefly population was comparatively higher in the early stage of the plant during July. Among varieties, JS 20-34 (48.16%) was highly affected by yellow mosaic disease, followed by MACS 1520, JS 335 and NRC 86. At the time of YMD initiation or early stage of disease spread, high temperature (min 25.0°C to max 33.5°C), low rainfall, comparatively less humid conditions (60.0-85.0%) coupled with a high whitefly population may lead to the severe spread of disease in the field in an upcoming fortnight. Whitefly had significant positive and negative relations with maximum temperature and wind speed. Similarly, maximum temp and sunshine hours had a negative significance and evening RH and wind speed had a positive significant relation with YMD progression.

ACKNOWLEDGEMENT

The authors sincerely thank the Head of the Department of Plant Breeding and Genetics, the Head of Plant Pathology and other field staff for their support and guidance during the investigation. They also express their gratitude to the university's In-charge meteorological observatory for providing weather data for analysis.

Conflict of interest

The authors declare that they have no conflict of interest

REFERENCES

Ahirwar, R., Devi, P. and Gupta R. (2015). Seasonal incidence of major insect pests and their biocontrol agents of soybean crop [*Glycine max* (L.) Merrill]. Scientific Research and Essays. 10(12): 402-406.

Amrate, P.K. (2024). Survey and Present Status of Soybean Diseases in Central India. International Journal of Bio-resource and Stress Management. 15(5): 01-10. doi: HTTPS://doi: ORG/10.23910/1.2024.5299.

Amrate, P.K., Chaukikar, K., Kharte, S., Pancheshwar, D.K., Marabi, R.S., Shrivastava, M.K. and Bhale, M.S. (2024). Distribution of charcoal rot of soybean, its influencing factors and pathogenic variabilities in different regions of Madhya Pradesh. Legume Research. doi: 10.18805/LR-5262.

Amrate, P.K., Pancheshwar, D.K., Shrivastava, M.K. (2018). Evaluation of soybean germplasm against Charcoal rot, Aerial blight and Yellow mosaic virus disease in Madhya Pradesh. Plant Disease Research. 33(2): 185190.

Amrate, P.K., Shrivastava, M.K. and Pancheshwar D.K. (2020b). Yield reduction and efficacy of antiviral product against yellow mosaic virus disease in soybean. Journal of Oilseeds Research. 37 (Special Issue): 229-230.

Amrate, P.K., Shrivastava, M.K. and Singh, G. (2023b). Identification of Sources of Resistance and Yield Loss Assessment for Aerial Blight and Anthracnose/Pod Blight Diseases in Soybean. Legume Research. 46(11): 1534-1540. doi: 10. 18805/LR-4452.

Amrate, P.K., Shrivastava, M.K., Borah, M., Routhu, G.K., Sharma, S., Nataraj, V., Pancheshwar, D.K., Singh, G. (2023a). Molecular characterization of soybean yellow mosaic virus isolates and identification of stable resistance sources in central India. Australasian Plant Pathology. 52:165-179. https://doi: org/10.1007/s13313-022-00902-8.

Amrate, P.K., Shrivastava, M.K., Pancheshwar, D.K. (2021) Crop-weather based relation and severity prediction of Aerial blight incited by *Rhizoctonia solani* Kuhn in soybean. Journal of Agrometeorology. 23(1): 66-73.

Amrate, P.K., Shrivastava, M.K., Pancheshwar, D.K., Stuti, S. (2020a). Charcoal rot and yellow mosaic virus disease of soybean under hot spot condition: symptoms, incidence and resistance characterization. International Journal of Bio-resource and Stress Management. 11(3): 268-273. doi: HTTPS://doi: ORG/10.23910/1.2020.2104.

Anonymous. 2019. 49th Annual Group Meeting Birsa Agricultural University, Ranchi. In: Proceedings and Technical Programmes (2018-19). ICAR-Indian Institute of Soybean Research. March 16-18. 59p.

Banerjee, J., Shrivastava, M.K., Amrate, P.K., Singh, Y., Upadhyay, A., Soni, M. (2022). Genetic variability and association of yield contributing traits in advanced breeding lines of soybean. Electronic Journal of Plant Breeding. 13(2): 597-607.

Banerjee, J., Shrivastava, M.K., Singh, Y. Amrate, P.K. (2023). Estimation of genetic divergence and proximate composition in advanced breeding lines of soybean [*Glycine max* (L.) Merrill]. Environment and Ecology. 41(3C). 1960–1968. https://doi.org/10.60151/envec/VYWE5744.

Barela, A., Shrivastava, M.K., Mohare, S., Rahangdale, S., Jawarkar, S., Amrate, P.K., Singh, Y. (2022). Morphological characterization and recognition of new traits of soybean [*Glycine max* (L.) Merrill]. International Journal of Environment and Climate Change. 12(12):1497-1504.

Bisht, K., Yadav, S.K., Karnatak, A.K., Gaur, N. (2017). Resistance against whitefly *Bemisia tabaci* and Yellow Vein Mosaic in Soybean. Indian Journal of Entomology. 79(4): 535-537.

Butler, G.D., Henneberry, T.D., Clayton, T.E. (1983). *Bemisia tabaci* (Homoptera: Aleyrodidae): Development, oviposition and longevity in relation to temperature. Annals of the Entomological Society of America. 76: 310-313.

Hartman, G.L. and Hill, C.B. (2010). Diseases of soybean and their management. The soybean: Botany, Production and uses. 276-299.

Jawarkar, S., Shrivastava M., Amrate P.K., Satpute G.K., Khare, V. (2023). Comprehensive analysis of phenotypic variation and selection strategies for yield-related traits in recombinant inbred lines of soybeans. Electronic Journal of Plant Breeding. 14(4): 1337-1344. https://doi: org/10.37992/2023.1404.165.

Kalkal, D., Lal, R., Dahiya, K.K., Singh, M., Kumar, A. (2015). Population dynamics of sucking insect pests of cotton and its correlation with abiotic factors. Indian Journal of Agricultural Research. 49(5): 432-436. doi: 10.18805/ijare.v49i5. 5806.

Kumar, B., Talukdar, A., Verma, K., Girmilla, V., Bala, L., Lal, S.K., Singh, K.P., Sapra R.L. (2014). Screening of soybean [Glycine Max (L.) Merr.] Genotypes for yellow mosaic virus (ymv) disease resistance and their molecular characterization using RGA and SSRs markers. Australian Journal of Crop Science. 8(1): 27.

Kumar, S., Amrate, P.K., Upadhyay, A., Paroda, M., Mohare, S. (2022). Influence of yellow mosaic disease on biochemical and yield attributing traits in soybean. Plant Disease Research. 37(2): 192-197. doi: No. 10.5958/2249-8788.2022.000 32.4

Kumar, S., Kumari, V., Kumar, V. (2020). Genetic variability and character association studies for seed yield and component characters in soybean [*Glycine max* (L.) Merrill] under North-western Himalayas. Legume Research. 43(4): 507-511. doi: 10.18805/LR-4006.

Liu, K.S., (2000). Expanding Soybean Food Utilization. Food Technology. 54(7): 46-58.

Marabi, R.S., Chaukikar, K., Das, S.B., Bhowmick, A.K. (2017b). Population dynamics of whitefly, *Bemisia tabaci* and incidence of mungbean yellow mosaic India virus (MYMIV) on blackgram. International Journal of Bio-resource and Stress Management. 8(6): 846-852. doi: HTTPS://doi: ORG/10.23910/IJBSM/2017.8.6.3C0371.

Marabi, R.S., Das, S.B., Bhowmick, A.K., Pachori, R., Vibha, Sharma H.L. (2017a). Seasonal population dynamics of whitefly (*Bemisia tabaci* Genn.) in soybean. Journal of Entomology and Zoology Studies. 5(2): 169-173.

Nene, Y.L. (1972). Viral disease of some warm weather pulse crop in India. Plant Disease Reports. 57: 463-467.

Nyvall, R.F. (1989). Diseases of Soybeans, In Field Crop Diseases Handbook, Springer US: Boston, MA, 503-559.

Parle, M., Bansal, N., Kaura, S. (2014). Take soybean to remain evergreen. International Research Journal of Pharmacy. 4(1): 1-6.

Raghuvanshi, S., Singh, P., Chauhan, P. (2014). Succession and incidence of insect pests of soybean [*Glycine max* (L.) Merrill] in Gird Region of M.P. Trends in Biosciences. 7(3): 207-209.

Rajput, L., Nataraj, V., Kumar, S., Amrate, P.K., Jahagirdar, S., Huilgol S.N., Chakruno, P., Singh, A., Maranna, S., Ratnaparkhe, M. B., Borah, M., Singh, K. P., Gupta, S., Khandekar, N. (2021). WAASB index revealed stable resistance sources for soybean anthracnose in India. Journal of Agricultural Science. 159(9-10): 710-720. doi: 10.1017/S002185962 2000016.

Ramlal, A., Nautiyal, A., Lal, S.K., Chigeza, G. (2023). Editorial: A wonder legume, soybean: prospects for improvement. Frontiers in Plant Science. 14:1294185. doi: 10.3389/ fpls.2023.1294185.

Sagarika, M., Amrate, P.K., Yadav, V.K., Shrivastava, M.K. (2023). Exploring potential of new generation fungicides as seed dresser in combating early infection of *Macrophomina phaseolina* in soybean. Indian Phytopathology. 76: 1045-1053. https://doi.org/10.1007/s42360-023-00680-3.

Sharma, S.S. and Kumar, Y. (2014). Influence of abiotic weather parameters on population dynamics of whitefly (*Bemisia tabaci* Genn.) on cotton. Journal of Cotton Research Development. 28(2): 286-288.

Silodia, K., Bhale, U., Bhale, M.S. (2018). Status and evaluation of soybean varieties against Mungbean Yellow Mosaic (MYMD) disease under changing climatic conditions of Kaymore plateau zone, Madhya Pradesh, India. Indian Journal of Agricultural Research. 52(6): 686-690. doi: 10.18805/ IJARe.A-5041.

Singh, K.P. and Aravind, T. (2019). Identification of resistant sources against soybean yellow mosaic and soybean mosaic diseases in field evaluation of soybean [*Glycine max* (L.) Merr.] Genotypes. Indian Phytopathology. 72: 519-521. https://doi: org/10.1007/ s42360-019-00168-z.

Singh, P.K., Rai, N., Verma, A. and Singh, D.V. (2009). Dolichos yellow mosaic virus influenced by environmental conditions. Annals of Plant Protection Sciences. 17(1): 164-166.

Srivastava, A.K., Marabi, R.S., Lalit, M. Bal and Yogranjan. (2021). Weather based rules for yellow mosaic disease prediction on soybean in Madhya Pradesh. Indian Journal of Biochemistry and Biophysics. 58: 486-497.

Swathi, M., Gaur, N., Singh, K. (2023). Virus Vector Relationship of Yellow Mosaic Virus and Whitefly, Bemisia tabaci (Gennadius) in Soybean. Legume Research. 46(7): 946-950. doi: 10.18805/LR-4479.

Talukdar, A., Harish, G.D., Shivakumar, M., Kumar, B., Verma, K., Lal, S.K., Sapra, R.L., Singh, K.P. (2013) Genetics of yellow mosaic virus (YMV) resistance in cultivated soybean [*Glycine max* (L.) Merr.]. Legume Research. 36(3): 263-267.

Uikey, S., Sharma, S., Amrate, P.K., Shrivastava, M.K. (2022). Identification of Rich Oil-Protein and Disease Resistance Genotypes in Soybean [*Glycine max* (L.) Merrill]. International Journal of Bio-resource and Stress Management. 13(5): 497-506. doi: https://doi.org/10.23910/1.2022.2478.

Upadhyay, P., Shrivastava, M.K., Amrate, P.K., Yadav, R.B. (2020). Yield determining traits, genetic variability and character association in exotic lines of soybean [*Glycine max* (L.) Merrill]. Soybean Research. 18(2): 95-102.

USDA. 2022. World Agricultural Production. United States Department of Agriculture. Foreign Agricultural Service, Washington. Varma, A. and Malathi, V.G. 2013. Emerging geminivirus problems: a serious threat to crop production. Annals of Applied Biology. 142: 145-164.

Wheeler, B.E.J. (1969). An introduction to plant disease. John Willey and Sons, London. pp 374.