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Research Article

IMPACT OF WEATHER PARAMETERS ON BEAN COMMON MOSAIC VIRUS (BCMV) OUTBREAK IN RAJMASH CROP OF HIGH ALTITUDE AND TRIBAL ZONE IN ANDHRA PRADESH

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Abstract: French Bean (*Phaseolus vulgare* L.), one of the most important pulse crops in the world, yields very little because of biotic or abiotic stressors. Field surveys were conducted to find out the influence of weather factors and their association with aphids population and Bean Common Mosaic Virus (BCMV) incidence in Rajmash during rabi seasons of 2018-2022 in High Altitude and Tribal Zone in Andhra Pradesh. Maximum temperature, mean relative humidity and rainfall play an important role in aphids population built-up and significantly related to its peak population. The correlation coefficients were found to be 0.78 for maximum temperature, -0.80 for mean relative humidity and -0.53 for rainfall. The preceding week weather conditions and aphids population as well as highest disease incidence week's rainfall act as determinant for BCMV outbreak. A regression model was developed utilizing these three variables and it was found that the model explained 65 per cent variability of the BCMV outbreak. BCMV outbreak may be estimated through minimum temperature and aphids population of the 32-44th SMW and rainfall of 32-44th SMW. The present analysis enables scientists to devise a system to monitor and develop management strategies for the control of BCMV disease and aphids vector.

Keywords: *Rajmash, BCMV, Weather factors, Correlation, Forewarning model*

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Introduction

Rajmash (*Phaseolus vulgare* L.) is important crop of India and is grown under mono, mixed and multiple cropping systems during rabi season under narrow range of agro-climatic conditions. In Andhra Pradesh, its cultivation is mainly confined to Alluri Sitarama Raju district. The productivity of Rajmash is very low in High Altitude Tribal Zone due to its cultivation on marginal lands under poor management. The major constraints responsible for lower yield potential are inappropriate production technologies *viz*., broadcast method of sowing, usage of BCMV susceptible local varieties, no use of fertilizer and untimely weed management [1]. Among the varieties cultivated in Alluri Sitarama Raju district; Chintapalle red alone contributes more area of Rajmash. Bean common mosaic virus (BCMV) is a major constraint to the cultivation of grain legumes in India, particularly rajmash. The viral diseases of pulses account upto 80 per cent yield losses with poor quality of seed, while the BCMV alone is capable to produce losses up to 80 to 100 per cent in Rajmash. From a biotic point of view, diseases are one of the main reasons for low production. Various viral diseases, including the bean mosaic virus (BCMV), the bean yellow mosaic virus (BYMV), the broad bean mosaic virus, the bean leaf roll virus (BLRV), the bean distortion dwarf virus (BDDV), the mung bean mosaic virus (MBMV), the bean seed borne mosaic virus, the dendrobium mosaic potyvirus (DeMV), the bean southern mosaic virus (BSMV), the bean Pod Mottle virus, and the bean mild mosaic virus, attack this crop (BMMV). Among all viral diseases, Bean Common Mosaic is a significant disease that causes significant yield losses. There isn't currently a single strain of this disease that is resistant. Among all the viruses, Bean common mosaic virus (BCMV) is the most destructive one and spreads mainly through aphids. The BCM virus is not seed or soil borne. Since the temperature of insects is roughly the same as the surroundings, temperature has a significant impact on the distribution and predominance of aphids. In Rajmash during the monsoon season, the weather conditions have a significant impact on the survival and growth of aphids as well as the BCMV outbreak. Understanding climatic conditions and their relationship to BCMV incidence is therefore necessary to offer baseline data for creating disease prediction systems. Finding the favourable weather conditions for the BCMV outbreak and developing a weather-based forewarning model were the study's major objectives.

Material and Methods

Field surveys were conducted to obtain the aphids population and BCMV incidence data in Rajmash in three blocks of Alluri Sitarama Raju district (17°87' North latitude, 82°35'East longitude and 839 meter height above msl). The data were collected from the farmer's field on local variety Chintapalle Red cultivated under rainfed conditions during rabi season in 2018 to 2022. The data were taken at weekly intervals starting from 32nd standard meteorological week (SMW) to 44th SMW from 2018 to 2022. The data of aphids population and BCMV incidence were recorded in the field under their natural incidence without any insecticidal intervention.

In the years 2018, 2019, and 2020 the crop was sowed during the first week of August, and in the years 2021 and 2022, during the second week of August. At the end of October and the middle of November, the crop was harvested. The India Meteorological Department's meteorological station (located at AMFU, RARS, Chintapalle) collected daily weather data on rainfall, maximum and minimum temperatures, and relative humidity for morning and afternoon hours. Weekly values were then calculated for conventional meteorological weeks (SMW). Before analysis, the accuracy of the weather data was verified.

Table-1 Area, production, yield of Rajmash and BCMV incidence in Alluri Sitarama Raju, District

Year	Area (000, ha)	Production (000, tones)	Yield (kg/ha)	BCMV mean incidence (%)
2018	9.54	5.72	652	32.6
2019	7.08	3.54	554	27.1
2020	7.73	4.64	616	29.0
2021	9.23	5.53	631	25.2
2022	8.14	4.88	624	23.1

Table-2 Correlation between weather parameters, aphids population and disease incidence

Variable	Weather Factors					
	Maximum temperature	Mean temperature	Morning Relative humidity (%)	Afternoon Relative humidity (%)	Rainfall (mm)	Disease incidence
Aphids population	0.61*	0.45	-0.51*	-0.59*	-0.54*	0.77**
Per cent BCMV incidence	0.42	-0.25	-0.42	-0.39	-0.55*	-

Collecting data on insects and diseases

Five leaves were randomly selected from 10 plants in each field, so that the aphid population count took into account the top leaf from the first plant, the middle leaf from the second plant, the bottom leaf from the third plant, and so on.

When the crop was 45 days old, a field survey was conducted in the Rajamsh fields of three villages in three blocks, namely Genjigedda, D. Chitalaveedi, and killoguda in the Alluri Sitarama Raju district, to determine the prevalence of the BCMV disease. Each village had two fields, and one square metre of land was selected at random in each field. Both the total number of plants and the number of plants showing the typical Bean common mosaic symptoms were counted. The following formula was used to compute the percent incidence (PI):

Percent incidence = No. of plants infected/m² area / Total no. of plants/m²area ×100 (1)

Statistical analysis

A statistical analysis of the data was performed, and averages were computed. Significant levels of P <0.05 and P <0.01 were used. To determine co-relations, the data were subjected to regression and correlation analysis. Based on the t and F test, the significance of correlation and regression was evaluated. To determine the BCMV outbreak, step-wise regression analysis was used.

Results and Discussion

Weather during crop period

The daily weather data from 06th August (32nd SMW) to 04th November (44th SMW) were converted into weekly data and mean values were computed and presented in [Fig-1]. During the crop period a total rainfall of 353.8, 749.4, 903.8, 815.9 and 546.1 mm was received during 2018, 2019, 2020, 2021, and 2022 respectively. The maximum temperature varied from 24.8 (2020) to 32.7 (2019) and minimum temperature ranged between 9.80 (2018) and 23.5 (2021). The mean weekly relative humidity varied from 84.4 (43rd SMW) to 89.6 (38th SMW) per cent during the crop period.

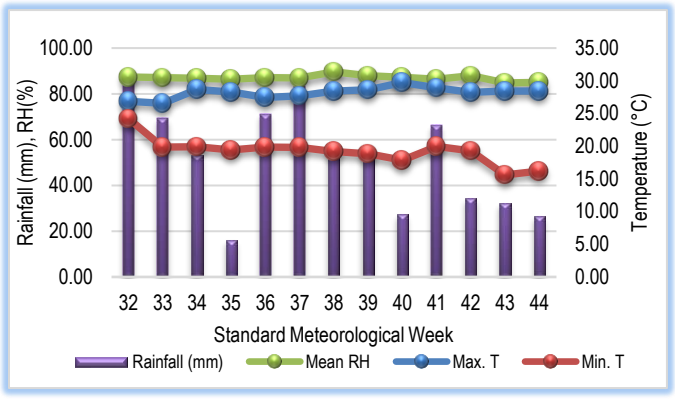

Fig-1 Mean weekly weather pattern during rabi 2018-22 at Alluri Sitarama Raju District

Aphids population and BCMV incidence during the study period

Distribution of aphids population in different blocks was recorded from farmer's fields and mean weekly values were computed. The weekly mean population of aphids, from 32nd SMW to 44th SMW, is presented in [Fig-2]. A perusal of this figure indicates that it started rising from 4 insects during first week of August and reached up to 16, the highest in the fourth week of September. Population started decreasing continuously from the fourth week of September till the first week of November. Similar trend of aphids population was found for the district however, the population was differed within the blocks with a slight variation between villages. Higher incidence of aphids was observed in the late sown Rajmash.

The cultivar Chintapalle red was low to moderate incidence of the disease was observed. The disease incidence was highest during 2018 followed by 2020, 2019, 2021 and 2022. The incidence of disease was observed from the 3 week after sowing and highest incidence was observed between 36 to 41st SMW. There was a lag of 1-2 weeks between highest aphids population and disease incidence. It was noticed that the crop infected at early stages suffered more with severe symptoms with almost all the leaves exhibiting mosaic and complete yellowing and puckering. Invariably aphids were found feeding in most of the fields surveyed.

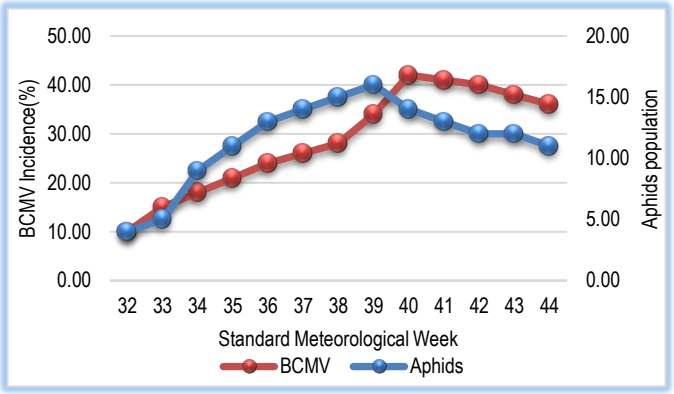

Fig-2 Weekly distribution of aphids population and BCMV incidence in Rajmash at Alluri Sitarama Raju District

Yield and disease incidence

The incidence of BCMV affected the yield of Rajmash and district level year-wise area, production, yield, and disease incidence is shown in [Table-1]. It was observed that disease incidence on reproductive stage of crop is very detrimental. Lowest yield was observed during the year 2018 and highest yield during the year 2020. Though the incidence of the disease was highest during the year 2018, but the lowest yield of 2018 was due to uneven distribution of rainfall and disease incidence at pod bearing stage. Singh et al. (1982) [2] reported that high disease attack at pod bearing stage is a major set back for pulses yield and it also delayed the pod maturity. The rajmash yield varied between 501 kg/ha to 1012 kg/ha.

Association of aphids population and weather factors

Temperature and rainfall influence the aphids population and dynamics [3]. To find out the association of aphids population with weather parameters, data were pooled and correlation coefficients were worked out between weather parameters and aphids population. The data on the above analysis is shown in [Table-2], which shows that there was a significantly positive correlation between temperature variations and aphids population; whereas humidity was negatively correlated with the aphids population. These findings agree with the findings of Rote and Puri (1991) [4] and Wahla *et al*. (1996) [5], who reported a positive and negative correlation of the aphids population with temperature and relative humidity, respectively. A non-significant and positive correlation between the mean temperature and aphids population was also found; whereas a negative and significant association was observed with the rainfall. Sudden heavy rainfall was negatively correlated with sucking pest population [6].

However, reported that with increase in temperature and relative humidity, population of aphids also increased. Malik and Sachan (2013) [7] reported that aphid population had non-significant positive relation with maximum temperature and non–significant negative correlation was observed with mean relative humidity. Ahmad et al., (2016) [8] reported that the significant variation in aphid population buildup seen during different dates ranging from 24-02-2013 to 03-04-2013 could be due to crop growth stage and environmental factors *e.g.*, temperature, relative humidity, and rainfall. Climatic factors considerably influence the aphid pest populations [9]. Temperature is considered the most important abiotic factor affecting physiology, aphid reproduction rates [10] and, consequently aphid population dynamics [11]. Insects can function faster and more efficiently at higher temperatures. They can feed, develop, reproduce, and disperse when the climate is warm, though they may live for a shorter time [12]. Two model studies indicated that temperature was highly linked with the density of aphid or other sucking insects [13,14]. Aphid population build up was regulated by temperature and time and population was relatively short in warm humid climates than in cool climates [15]. Dhaliwal *et al*. (2007) [16] stated that the incidence, growth and multiplication of mustard aphid are largely influenced by meteorological parameters like temperature, relative humidity, rainfall, wind speed and cloudiness. Ansari *et al.* (2007) [17] also reported that the peak aphid population was found at a maximum, minimum and average temperature of 23.37°C, 6.87°C and 15.76°C, respectively and mean relative humidity of 54.75% on 10th February at 90 days after sowing.

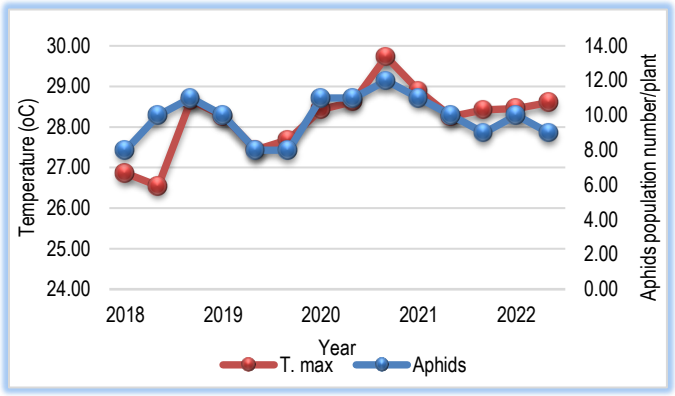

Fig-3 Weekly pattern of peak aphids population and corresponding week's maximum temperature in Rajmash

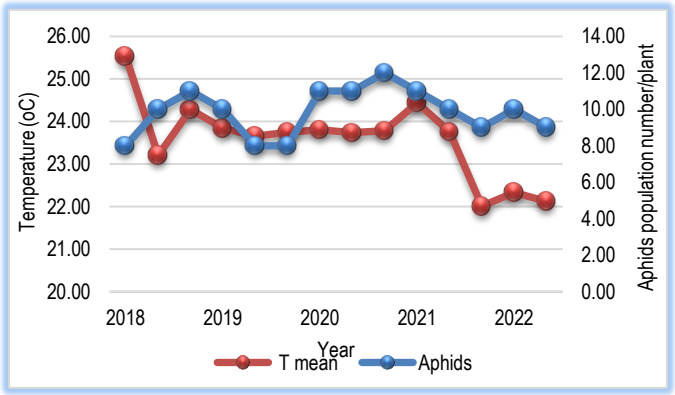

Fig-4 Weekly pattern of peak aphids population and corresponding week's mean temperature in Rajmash

Correlation between peak and preceding weather and aphids population

Correlation coefficient between peak aphids population (36-41st SMW) and corresponding week's weather parameters were worked out and correlation coefficients values of highly correlated weather variables are given below:

Maximum temperature	:	0.78**,
Mean temperature	:	0.68**
Rainfall	:	-0.53*
Mean relative humidity	:	-0.80**

(*Significant at 5% level, ** Significant at 1% level)

It is observed that dry weather conditions with maximum temperature of 25°C to 31°C during peak population week coupled with low to medium rainfall (0.0 to 50mm/week) are found to be congenial conditions for the peak aphids population.

Correlation coefficient between peak aphids population (36-41st SMW) and preceding week's weather (32-35th SMW) were worked out and it is observed that correlation between preceding week weather parameters and peak aphids population were non -significant.

Maximum temperature ranged from 24.8°C to 32.7°C [Fig-3], while the mean temperature ranged from 22°C to 24.4°C [Fig-4] during peak aphids population weeks. The mean relative humidity varied between 84.8 and 89.6 per cent [Fig-5] corresponding to 0.0 to 88.3 mm weekly rainfall and was observed to peak aphids population. The ability of insects to survive thermal stress, together with other factors, plays an important role in determining distribution of a species [18]. aphids adults survival was affected by temperature regime of 26°C to 39°C. Their survival was upto 41°C and above this maximum temperature; adults were showing dying symptoms and got killed by 45°C [19]. There was no correlation between the aphid population and rainfall. Although the relative humidity levels had a positive impact on the aphid population, they were not statistically significant.

Association of BCMV incidence and weather factors

Higher temperature has been found to be positively correlated with aphids population in 20-30 days old crop and with symptoms of disease incidence in 45 days old crop. In the Alluri Sitarama Raju district, Chintapalle block has shown the highest (29.3 %) disease incidence followed by Paderu, and Araku valley with 26.2 and 24.5 percent, respectively. The variation in disease incidence over locations might be due to the local variation in temperature and relative humidity that may have direct influence on vector population and its migration. The effect of climate on biology and distribution of vector, (Aphis gossypii) was earlier discussed by Singh and Gurha (1994) [20].

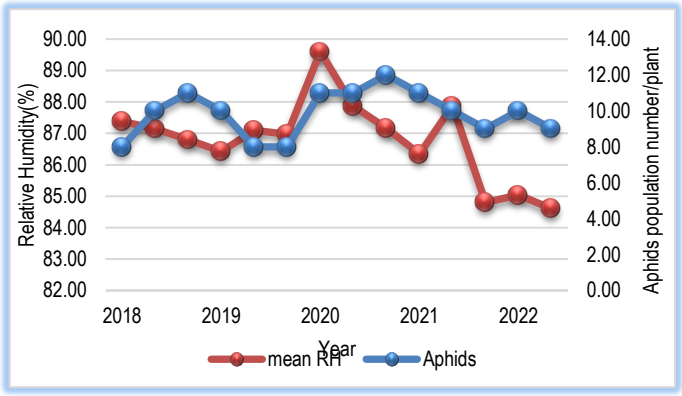

Fig-5 Weekly pattern of peak aphids population and corresponding week's mean RH in Rajmash

Correlation between peak BCMV incidence and weather parameters

It was noticed that corresponding as well as preceding week's weather and aphids population have influenced the peak incidence of the disease in the study period. The correlation coefficients between peak disease incidence (39-44th SMW) weeks with corresponding week (32-38th SMW) weather were calculated. The high correlation coefficient values were only found for minimum temperature (0.34) and rainfall (-0.37). The preceding week's weather parameters (32-39th SMW) and peak disease incidence week were also correlated and minimum temperature was significantly correlated (0.53) with incidence of disease.

Weather based MYMV forewarning model

To estimate the cumulative effects of different weather parameters and aphids population on disease outbreak; regression analysis was carried out; following step wise regression analysis. The outbreak or highest disease incidence was recorded during 39-44th SMW and highly correlated with aphids population and minimum temperature (39-44th SMW), rainfall of moderate incidence period (39-44th SMW) were taken into consideration for working out the predictive model after pooling the data. The equation for the prediction of outbreak is

$Y= -165+9.4X_1-0.05X_2-0.2X_3$, $R^2=0.65$* (2)

Standard error =12.3, *Significant at 5% level

Where

Y = BCMV % incidence on Rajmash

X_1 = Minimum temperature of preceding week (35-37th SMW)

X_2 = Peak aphids population of preceding week (37-41st SMW)

X_3 = Rainfall during highest BCMV incidence week (39-44th SMW)

It is found that minimum temperature, afternoon relative humidity, rainfall and aphids population are the major determinants of BCMV disease incidence. These parameters explained 65 percent variability of disease outbreak in Rajmash. The dependent variables are available at district level in High Altitude Tribal zone which may be utilized for estimation of BCMV outbreak. District level medium range weather forecast round the years is also provided by India Meteorological Department to all the blocks of this districts.

Based upon these three variables a BCMV watch and tactical management box was prepared and is presented below

A+B+C+

Outbreak - Control measures

A+B+C-

Alarm- Prophylactic spray

A+B-C-

Congenial- Keep watch

A-B-C-

No threat - No Action

Where

A+ : When minimum temperature of 37-41st SMW is above normal

A- : When minimum temperature of 37-41st SMW is below normal

B+ : When mean aphids population of 37-41st SMW is around 15/plant or above

B- : When mean aphids population of 37-41st SMW is much below 15/plant

C+ : When weekly rainfall of 37-41st SMW is upto 50 mm/week

C- : When weekly rainfall of 37-41st SMW is above 50 mm/week or heavy rainfall

The above simple rules may be utilized in formulation of bi-weekly district level Agromet advisory bulletins and by extension workers to make tactical decisions for BCMV control measures.

Conclusion

The Rajmash variety Chintapalle red which occupied 70 percent of the area in the district under study was found moderate susceptible to BCMV disease during the survey. The reported observations of this study may enable the scientists to devise a system to monitor and develop management strategies in controlling the spread of bean common mosaic virus disease and the vector aphids, Aphis gossypii and to screen resistant Rajmash varieties for this disease for this region. From the present study it was concluded that out of five weather variables, only minimum temperature and rainfall had statistically significant correlation with BCMV outbreak. Rise in maximum temperature was conducive for development of disease; while increase in relative humidity and heavy rainfall was detrimental to aphids population. These findings can be used to develop a disease forecasting model for judicious application of chemicals. Long term data on disease incidence should be utilized for refinement of the predictive model and its validation under difference thermal and moisture regimes before putting it into operational use.

Application of research: Study of monitor and develop management strategies for the control of BCMV disease and aphids vector

Research Category: Cropping system

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Research project name or number: Research station study

Author Contributions: All authors equally contributed

Author statement: All authors read, reviewed, agreed and approved the final manuscript. Note-All authors agreed that- Written informed consent was obtained from all participants prior to publish / enrolment

Study area / Sample Collection: Regional Agricultural Research Stations, Chintapalle, 31111

Cultivar / Variety / Breed name: French Bean (*Phaseolus vulgare* L.)

Conflict of Interest: None declared

Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.
Ethical Committee Approval Number: Nil

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