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Seasonal incidence of whitefly, *Bemisia tabaci* (Gennadius) and yellow mosaic disease (YMD) on blackgram in Southern zone of Andhra Pradesh

C Raghu Prasad, KV Hari Prasad, GS Panduranga and AR Nirmal Kumar

Abstract
A field experiment was conducted at S.V. Agricultural College, Tirupati, Chittoor district, Andhra Pradesh during late *rabi* 2020-21 to know the effect of date of sowing on incidence of whitefly and Yellow mosaic disease on blackgram and its correlation to weather parameters. The experiment was conducted at four different dates of sowing (first at November 1st, second at November 15th, third at December 1st and fourth at December 15th) with a susceptible variety LBG-623. The results revealed that among the four dates of sowing, November 1st sown crop recorded the lowest mean number of whitefly population and YMD incidence (3.50 adults/plant and 21.96 percent disease incidence) than November 15th (4.60 adults/plant and 33.71 PDI), December 1st (6.20 adults/plant and 67.44 PDI) and December 15th (7.20 adults/plant and 73.00 PDI). Correlation studies revealed that weather parameters *viz.*, maximum temperature positively correlated with disease development whereas, evening relative humidity and rainfall were negatively correlated with disease development. Maximum temperature, morning relative humidity and rainfall significantly negatively correlated with whitefly population.

Keywords: Seasonal incidence, YMD, whitefly, blackgram

Introduction
Blackgram (*Vigna mungo* (L.) Hepper) commonly known as urdbean, mash or black mapte is a short duration and highly remunerative pulse crop grown in most parts of India traditionally as *kharif* crop. India currently represents the largest producer of blackgram accounting for more than 70 percent global production followed by Myanmar, Pakistan and Thailand (Sasidhar *et al*., 2022) [19]. Though traditionally a *kharif* crop, in state of Andhra Pradesh, it is being cultivated mostly as *rabi* (winter) crop both in uplands and rice fallows and contributes 10 percent of the national pulse production (Rajawat *et al*., 2021) [17].
Blackgram crop is attacked by variety of sucking insect pests of which whitefly (*Bemisia tabaci* Gennadius) is the most important pest during early stages of crop growth which not only reduce the plant vigour but also act as vector of deadly viral disease, Mungbean Yellow Mosaic disease (MYMV) which is a serious threat to pulse production in India. The yield losses due to the disease varied from 5 to 100 percent depending upon the age of the crop, susceptibility of cultivars and population of whiteflies (Mahalakshmi *et al*., 2015) [11]. In Chittoor district which represents the Southern Zone of Andhra Pradesh, blackgram is cultivated in 3439 hectare with a production of 3997 tonnes and productivity of 740 kg ha^{-1}, which is far below the state average productivity (AP Agricultural statistics 2020-21). In changing climatic scenario, the incidence of whitefly and severity of yellow mosaic virus disease on blackgram are the major cause of unsuccessful cultivation of blackgram and low production in Chittoor district. However, information on the seasonal incidence of whitefly and MYMV in relation to weather parameters under southern zone of Andhra Pradesh is scanty. Hence the present study was carried out to generate location specific information on this aspect which would be helpful to develop management strategies for suppressing the insect pest population and YMD incidence.

Material and Methods
The experiment was conducted during late *rabi* 2020-21 at dryland farm S.V. Agricultural College Tirupati, Chittoor district, Andhra Pradesh. The experimental field was laid out with a susceptible variety LBG-623 in 10 x10 m plot at four different dates November 1st (D_1-Early

sowing), November 15th (D_2-Mid sowing)), December 1st (D_3-mid sowing) and December 15th (D_4-Late sowing) to study the seasonal incidence of whitefly and YMD. During the period of study, whitefly population from experimental area was molecular characterized as described by Singh *et al*., (2012) using *mt*COI primers, forward primer C1-J-2195 (5-TTGATTTTTTGGTCATCCAGAAGT-3) reverse primer L2-N-3014 (5-TCCAATGCACTAATCTGCCATATTA-3) Simon *et al*., (1994) to determine the genetic group or biotype of whitefly. It has been observed that whitefly species exists as a species complex with morphologically similar but different at genetic level giving raise to several biotypes.

Studies on *B. tabaci* reveal convincing evidence of at least 35 cryptic species with extensive genetic diversity and which show diverse behaviour concerning host plant preference, oviposition, ecological adaptation as well as virus dissemination (Ahmed *et al*., 2013: De Barro, Trueman, & Frohlich, 2005) [1, 5]. Even in the same genetic group such as *B. tabaci*, different subclades can differ in important aspects of biology such as virus transmission, fecundity and mating ability (Habibu *et al*., 2012) [8].

All the suggested cultivation practices (ANGRAU) were followed except plant protection measures in order to buildup the population of whitefly and YMD in the field. The whitefly population (nymphs and adults) was recorded on randomly selected ten plants at weekly intervals from three leaves each from top, middle and bottom portions of the plant. For YMD incidence, five rows of ten meter length was selected randomly from the entire plot and total number of plants and plants with YMD disease symptoms was counted to estimate the percent disease incidence of YMD.

The data on percent disease incidence was calculated by using the following formula.

$$\text{Percent disease incidence (PDI)} = \frac{\text{Number of diseased plants per row}}{\text{Total number of plants per row}} \times 100$$

Weather data *viz.*, temperature (maximum and minimum), relative humidity (maximum and minimum), rainfall, rainy days, evaporation, and sunshine hours were recorded simultaneously (standard week wise) from the meteorological observatory of Regional Agricultural Research Station (RARS), Tirupati and used for correlation studies of whitefly population as well as disease incidence on blackgram.

Results

The genomic DNA from single whitefly isolated as described by Singh *et al*. (2012) [24] and used for amplification of mitochondrial cytochrome oxidase gene (*mt*COI) by gene specific primers. The amplified product of 880bp was purified and sequenced and deposited in GeneBank. The *mt*COI based molecular analysis revealed that *B. tabaci* population (Access on Number: OP 765654) in the present study was aligning to *B. tabaci* complex spp. Asia II-1 mitochondrion GenBank ID: JX 993219 (Sriganga Nagar) with 99% homology.

Effect of dates of sowing on whitefly incidence

In first date of sowing, the first appearance of whitefly was observed at 19 days (47th SMW) after sowing with a mean population of 0.67 adults per plant and reached its peak 3.50 adults per plant at 51st SMW (47 DAS). Thereafter the population gradually decreased to 0.50 adults per plant at 4th SMW (82 DAS) which coincides with maturity phase of the crop. In the second date of sowing, incidence was noticed from 48th SMW (15 DAS) with a mean population of 1.00 adult per plant and reached its peak 4.60 adults per plant at 52nd SMW (40 DAS). Thereafter the population gradually decreased to 0.80 adults per plant at 5th SMW (75 DAS) which coincides with maturity phase of the crop.

In the third date of sowing, incidence was noticed from 50th SMW (15 DAS) with a mean population of 2.30 adults per plant, gradually increased and reached its peak at 3rd SMW (45DAS) with a mean population of 6.20 adults per plant. Thereafter the population decreased to 1.90 adults per plant at 7th SMW (72 DAS) which coincides with maturity phase of the crop. In the fourth date of sowing, first incidence was observed at 52nd SMW (14 DAS) with a mean population of 1.80 adults per plant, gradually increased and reached peak at 3rd SMW (30 DAS) with a mean population of 7.20 adults per plant. Thereafter the population gradually decreased to 1.00 adult per plant at 10th SMW (76 DAS) which coincides with maturity phase of the crop (Table 1).

Effect of dates of sowing on YMD incidence

In the first date of sowing, Yellow Mosaic Disease (YMD) appeared on the crop at 48th SMW (26 DAS) with 1.20 mean percent disease incidence (PDI), gradually increased up to 2nd SMW-60 DAS (27.3%) and reached maximum disease incidence (29.16%) at 4th SMW (78 DAS). In the second date of sowing, Yellow Mosaic Disease (YMD) appeared on the crop at 49th SMW (18 DAS) with 2.40 mean percent disease incidence (PDI), gradually increased up to 1st SMW-45 DAS (42.56%) and reached its maximum at 5th SMW (49.05%-80 DAS). However the rate of increase in percent disease incidence was slow from 1st SMW to 5th SMW compared to 49th to 1st SMW.

In the third date of sowing, Yellow Mosaic Disease (YMD) appeared on the crop at 51st SMW (17 DAS) with 8.10 mean percent disease incidence (PDI), gradually increased up to 3rd SMW-45 DAS (60.35%) and reached its maximum at 7th SMW (67.4%-72 DAS). However the rate of increase in percent disease incidence was slow from 3rd SMW to 7th SMW compared to 51st to 3rd SMW. In the fourth date of sowing, Yellow Mosaic Disease (YMD) appeared on the crop at 52th SMW (15 DAS) with 0.40 mean percent disease incidence (PDI), gradually increased up to 4th SMW-43 DAS (66.36%) and reached its maximum at 10th SMW (73.00%-80DAS). However the rate of increase in percent disease incidence was slow from 4th to 10th SMW compared to 52nd to 4th SMW (Table 1).

Correlation of whitefly and YMD incidence on blackgram in relation to weather parameters during *rabi* 2020-21

Correlation studies revealed that whitefly population showed a significant negative correlation with maximum temperature (r= -0.62*) in 1st date of sowing, significant positive correlation with minimum temperature (r=0.78**) and evening relative humidity (r=0.44*) in 3rd date of sowing, significant negative correlation with rainfall (r=-0.33*) in 4th date of sowing, remaining all weather parameters did not show any significant correlation (Table 2).

The present results are in accordance with Shrivastva and Prajapati (2012) [26] reported that maximum temperature had negative influence on whitefly population in blackgram. Janu and dhahiya (2017) [9] and Phulse *et al*. (2014) [16] reported that similar findings in cotton. Bhowmik *et al*. (2017) [2] reported that all the weather parameters, showed a non-significant negative correlation with whitefly population in green gram.

Correlation studies revealed that YMD exhibited significant negative correlation with rainfall (r=-0.69*) in first date of sowing. Significant positive correlation with maximum temperature (r=0.64*), evaporation (0.67*) and negative correlation with evening relative humidity (r=-0.65**) in 2nd date of sowing, significant positive correlation with maximum temperature (r=0.83**), sunshine hours (r=0.89**) and evaporation (r=0.90**) and significant negative correlation with evening relative humidity (r=-0.72*) in 3rd date of sowing. In 4th date of sowing, significant positive correlation with maximum temperature (r=0.71*), sunshine hours (0.89**) and evaporation (0.90**) whereas, significant negative correlation with minimum temperature (r=-0.68*), evening relative humidity (=-0.88**) and rainfall (=-0.68*) (Table 2). Srinivasaraghavan (2014) [25] found that incidence of mungbean yellow mosaic virus (MYMV) disease had exhibited highly significant positive correlation with maximum temperature and significant negative correlation with morning relative humidity. Marabi *et al*. (2017) [13] and Patel and Mahatma (2016) [15] also reported that similar findings in in blackgram.

Correlation studies between whitefly population and YMD incidence revealed that except 1st date of sowing (r=-0.14), there was a positive correlation between whitefly population and YMD. (Table 2). The present results are in line with Sandhu and Singh (2019) [23] and Suman *et al.* (2016) [27] reported that positive correlation between whitefly population and YMD disease incidence in greengram.

Multiple linear regressions

Regression analysis of whitefly population with weather parameters of *rabi* 2020-21 revealed that all the weather parameters together influenced whitefly population to the extent of 96 percent (R^2=0.96) in first date of sowing, 96 percent (R^2=0.96) in 2nd date of sowing, 62 (R^2=0.62) and 75 percent (R^2=0.75) in 3rd date of sowing and 93 percent (R^2=0.93) in 4th date of sowing (Table 3). The present results are in agreement with Rohini (2010) [30] reported that variation in whitefly population due to all weather parameters was up to 66 percent in cotton. Singh and Sandhu (2019) [23] also developed regression models between weather parameters between whitefly population and weather parameters and showed that higher R^2 value (0.97) when maximum weather parameters involved.

Multiple linear regressions between YMD incidence and weather parameters revealed that all the weather parameters together responsible for a total influence of 86 percent (R^2=0.86) on YMD incidence in 1st date of sowing, 92 percent (R^2=0.92) in 2nd date of sowing, 88 percent (R^2=0.88) in 3rd date of sowing and 94 percent (R^2=0.94) in 4th date of sowing (Table 3). The present results are in accordance with Khan *et al*. (2006) [31] who performed a step wise regression analysis and it was seen that the influence of air temperature, relative humidity and rainfall was significant on whitefly population and MYMV spread in mungbean. Singh and Sandhu (2019) [23] revealed that all weather parameters are contributed equally for the disease spread with R^2 values (0.93).

Table 1: Influence of different dates of sowing on whitefly and YMD incidence in blackgram (LBG-623) during late *rabi* 2020-21.

SW	Date and Month	Temperature (°C)		Relative humidity (%)		Rainfall (mm)	SSH (hours/ day)	Evaporation (mm/day)	D1		D2		D3		D4	
		Max.	Min.	Mng.	Evg.				Whitefly/ Plant*	YMD (PDI)	Whitefly	YMD	Whitefly	YMD	Whitefly	YMD
47	19th-25 th Nov	29.63	20.07	84.86	58.43	14.91	6.14	4.19	0.67	0.00						
48	26th-2nd Dec	27.76	20.74	87.14	69.71	3.91	3.01	2.71	1.56	1.20	1.00	0.00				
49	3rd-9th Dec	27.29	22.03	94.00	80.43	16.77	1.64	1.44	3.00	4.02	2.10	2.04				
50	10th-16th Dec	28.39	17.41	84.71	65.71	0.00	6.96	3.83	3.40	12.88	3.60	5.06	2.30	0.00		
51	17th-23th Dec	28.83	18.47	79.43	54.57	0.11	4.90	3.43	3.50	17.96	4.30	16.04	3.50	8.10		
52	24th-31st Dec	28.14	18.11	83.63	55.88	0.00	4.10	4.08	2.70	21.76	4.60	33.71	3.80	19.89	1.80	0.40
1	1st-7 th Jan	27.41	21.13	85.71	70.29	6.23	2.90	3.30	2.00	24.62	3.20	42.56	5.50	21.72	2.90	8.52
2	8th-14th Jan	28.86	20.61	84.57	64.29	0.77	4.21	3.04	1.50	27.30	2.70	43.87	6.00	51.83	6.40	27.77
3	15th-21st Jan	30.09	17.93	84.71	51.57	0.00	7.89	4.24	1.20	28.24	2.10	45.56	6.20	60.35	7.20	58.43
4	22th-28th Jan	30.56	17.79	86.29	41.14	0.00	8.31	4.67	0.50	29.16	1.80	46.78	4.40	62.00	7.10	66.36
5	29 th-4th Feb	30.39	18.09	82.43	46.71	0.00	8.11	5.07			0.80	49.05	3.50	64.24	4.90	68.12
6	5th-11th Feb	30.06	14.93	84.14	43.14	0.00	8.77	5.31					2.10	65.46	3.20	69.98
7	12th-18th Feb	31.13	15.79	87.00	38.14	0.00	9.16	5.56					1.90	67.44	2.40	71.00
8	19th-25 th Feb	31.73	20.31	84.00	43.40	0.71	7.19	5.03							1.72	72.79
9	26th-4th March	35.53	17.19	70.00	23.57	0.00	9.00	6.51							1.41	72.79
10	5-11 march	36.20	18.56	74.35	36.72	0.00	7.34	6.20							1.00	73.00

*Whitefly mean of 10 randomly selected plants * YMD incidence: Average PDI of five rows D-Dates of sowing D_1: 1-11-2020 D_2:15-11-2020 D_3:1-12-2020 D_4: 15-12-2020 SSH: Sunshine hour Mng: Morning relative humidity Evg: Evening relative humidity SMW: Standard Meteorological week

Table 2: Correlation coefficients (r) between whitefly, YMD incidence and weather parameters on blackgram during late *rabi* 2020-21

Weather Parameters	Correlation coefficient (r)							
	Whitefly population				YMD incidence (PDI)			
	D_1	D_2	D_3	D_4	D_1	D_2	D_3	D_4
Maximum temperature (°C)	-0.62*	0.35^{NS}	-0.30^{NS}	-0.32^{NS}	0.40^{NS}	0.64*	0.83**	0.71*
Minimum temperature (°C)	-0.058^{NS}	-0.20^{NS}	0.78**	-0.15^{NS}	-0.44^{NS}	-0.30^{NS}	-0.30^{NS}	-0.68*
Morning relative humidity (%)	-0.083^{NS}	-0.37^{NS}	0.058^{NS}	0.36^{NS}	-0.38^{NS}	-0.37^{NS}	0.41^{NS}	-0.35^{NS}
Evening relative humidity (%)	0.435^{NS}	0.87^{NS}	0.44*	0.15^{NS}	-0.55^{NS}	-0.65**	-0.72*	-0.88**
Rainfall (mm)	-0.080^{NS}	-0.17^{NS}	0.40^{NS}	-0.33*	-0.69*	-0.46^{NS}	-0.27^{NS}	-0.68*
Sunshine hours (hr/day)	-0.40^{NS}	-0.21^{NS}	-0.50^{NS}	0.19^{NS}	0.39^{NS}	0.51^{NS}	0.67*	0.89**
Evaporation (mm/day)	-0.430^{NS}	-0.53^{NS}	-0.16^{NS}	-0.25^{NS}	0.46^{NS}	0.67*	0.68*	0.90**
Whitefly population Vs YMD					-0.14	0.33	0.43	0.17
YMD Vs Whitefly population	-0.14	0.33	0.43	0.17	---	---	---	---

*Significant at 5% level ** Significant at 1% level

D-Dates of sowing D_1: 1-11-2020 D_2:15-11-2020 D_3:1-12-2020 D_4: 15-12-2020

Table 3: Multiple regression analysis regarding the impact of weather parameters on whitefly population and YMD incidence in blackgram during late *rabi* 2020-21.

Treatment	Regression equation	R^2 value
Whitefly Vs weather parameters D1: (1st Nov)	$Y= 53.61-0.906 X_1-0.561 X_2-0.15 X_3-0.08 X_4-0.137 X_5+ 0.047 X_6+ 0.392 X_7$	0.96
D2: (Nov 15th)	$Y= 115.46-6.08 X_1+ 1.95 X_2 +0.475 X_3-0.413 X_4-5.63 X_5-0.976 X_6+3.64 X_7$	0.62
D3: (Dec 1st)	$Y= -31.40-0.175 X_1+0.784 X_2+0.379 X_3-0.09 X_4-3.15 X_5-0.09 X_6+1.09 X_7$	0.75
D4: (Dec15 th)	$Y= 149.39-3.88 X_1+1.710 X_2-0.655 X_3-0.304 X_4-1.79 X_5+0.019 X_6+3.02 X_7$	0.93
YMD incidence Vs weather parameters D1:(1st Nov)	$Y= -437.94+2.63 X_1+10.02 X_2+0.92 X_3+0.25 X_4+4.48 X_5-2.56 X_6+7.00 X_7$	0.86
D2: (Nov 15th)	$Y= -139.51-44.56 X_1+40.04 X^2+8.13 X_3-3.67 X_4-32.87 X_5-12.7 X_6+39.00 X_7$	0.92
D3: (Dec 1st)	$Y= -867.12+39.60 X_1+1.65 X_2-3.87X_3+1.856 X_4+60.42 X_5+ 2.787 X_6-27.74 X_7$	0.88
D4: (Dec 15th)	$Y= 813.95-20.03 X_1+3.468 X_2-1.184X_3-3.934 X_4+17.56 X_5-6.67 X_6-5.947 X_7$	0.94

X_1: Maximum temperature X_2: Minimum temperature X_3: Morning relative humidity X_4: Evening relative humidity X_5: Evaporation X_6: Rainfall X_7: sunshine hours R^2=Regression co efficient

Discussion

In the present study, in all the four different dates of sowing maximum number of whitefly population was observed from 30-47 days after sowing and also fastest disease spread between 40-55 days after spraying, coinciding with maximum vegetative stage and initiation of reproductive buds. Whitefly prefers to suck the phloem sap from the succulent part of the plant and as the plant become older its dry matter accumulation is increased with the age of the plant and thus reduces population of whitefly and its infestation as well Garg and Patel (2018) [6] and Shlokeshwar *et al*. (2015) [21] reported that population of whitefly and leafhopper increased with increase in the crop age up to reproductive stage. The present results are also in accordance with Shah *et al*. (2006) [27] who indicated that chances of disease spread are decreased with increased of crop maturity in mungbean.

Habib *et al*. (2007) [7] reported that crop is more sensitive to MYMV at early stage in mungbean rather than maturity. These results clearly indicate that the initial period of 3-4 weeks is highly critical due to early landing of viruliferous whitefly for the development and spread of YMD.

In the present study, among the four dates of sowings 1st date of sowing (November 1st –early sowing) recorded the lowest whitefly population and YMD disease incidence compared to remaining dates of sowing, it indicates that 1st date of sowing (Nov.1st sown crop) completes its physiological life cycle (vegetative and reproductive phase) during the period where weather conditions such as frequent rains (Chittoor district falls under the shadow of north east monsoon and receives its highest rains in the months of November and December) interfered with growth and multiplication of whitefly population thus leading to lowest disease incidence. These results were in accordance with the findings of Meghasree and Mallikharjuna (2018) [14] and Mahalakshmi *et al*. (2014) [12] reported that December to April sown mungbean crop leads to higher YMD disease incidence with low yields compared to June to November sown crop (early sowing). Rashid *et al*., (2013) [18] reported that March 15th sown mungbean crop recorded highest disease incidence (40.94%) with lowest yield (997 kg/ha).

Changes in maximum temperature had a significant impact on whitefly population. High temperature resulted in a decrease in the pest population due to fact that the immature stages of *B. tabaci* were desiccated when the temperature was high. (Cui *et al*., 2008) [32]. Lui *et al*. (2020) [33] reported that average relative humidity 65-70 percent was conducive to oviposition and survival of adults. Venugopal Rao and Reddy (1994) [28] and Butani and Jotwani (1984) [4] reported that activity of whitefly decreased with the onset of rains which is also in support to the results under present studies.

Conclusion

Date of sowing had direct impact on incidence of YMD and whitefly population, the experimental results concludes that early sowing of blackgram can escape the disease incidence and delayed sowing leads to higher disease incidence with lower yields. Hence, sowing of blackgram can be recommended during first week of November. From the present study also concluded that rise in maximum temperature was conducive for development of disease, while increase in relative humidity and heavy rainfall was detrimental to whitefly population.

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