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Study of Morpho-physiological and Biochemical Traits for Resistance to Yellow Mosaic Virus (YMV) in Blackgram [*Vigna mungo* (L.) Hepper] Varieties

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ABSTRACT

Background: Blackgram is one of the most important pulse crop in India and it is being affected by a number of insect pests from seedling stage to maturity. Among them whitefly is an important insect pest that transmit the viral disease, yellow mosaic virus (YMV), which is a major disease resulting in severe yield losses accounting for about 70% and infection at early stages may result in complete failure of the crop causing huge loss to the farmers economically. To overcome the losses due to this important disease in blackgram, study of host plant resistance to whiteflies, thereby minimizing the losses due to YMV disease is of great importance. The trichome density plays an important role as a morphological anti-feedant which reduces the pest attack and subsequently lowers the disease incidence and the plants with high trichome density showed less YMV symptom. The morpho-physiological and biochemical traits play an important role in host plant resistance against YMV disease through insect vector resistance and hence, the study was undertaken.

Mathods: A field experiment was conducted during *rabi* 2017-18 and 2018-19 at RARS, Lam, Guntur in a randomized block design with eight blackgram varieties and replicated thrice under receding soil moisture condition. The experiment was conducted using eight blackgram varieties (LBG 787, GBG 1, TBG 104, LBG 884, LBG 806, LBG 808, LBG 623 and LBG 752) obtained from RARS Lam, Guntur and the variety LBG 623 was considered as a susceptible check. The estimation of sugars, phenols, tannins, trichome density and SCMR was done at vegetative and reproductive stages of crop growth.

Result: A significant variation was observed among the varieties for all the traits observed at vegetative and reproductive growth stages during both *rabi* 2017-18 and 2018-19. The total sugar content of the blackgram varieties varied from 25.16 to 49.82 mgg^{-1} FW; the leaf phenolic content values ranged from 10.26 to 23.55 mg g^{-1} FW and the tannins content of the dried leaf samples ranged from 0.014 to 0.052 mgg^{-1} DW. The trichome density of the blackgram varieties varied from 12.91 to 74.59/cm^2 of leaf area and the SCMR values ranged from 24.21 to 55.17. Higher seed yield was recorded in the variety LBG 884 followed by GBG1 and the lower seed yield was recorded in the variety LBG 623 during *rabi* 2017-18 and 2018-19. The YMV resistant varieties showed relatively higher phenolic, tannins content and trichome density and lower total sugar content in the leaf. The total sugar content showed a significant negative correlation with the seed yield. The SCMR value was significantly lower in the susceptible varieties of blackgram with higher disease scores.

Key words: Biochemical traits, Blackgram, Morpho-physiological traits, YMV resistance.

INTRODUCTION

Blackgram is an important tropical pulse crop widely distributed in the South Asian countries. The higher protein and antioxidant concentration mainly anthocyanin which is the reason for its dark hue makes blackgram nutritionally more important. It is sometimes described as "poor man's meat" because of its balanced protein and carbohydrate diet when combined with cereal food grains. Blackgram is a rich source of dietary micronutrient Iron (Fe). The blackgram production in India accounted for more than 25% of the world with 25.23 Million tonnes (Mt) during 2017-18 over a cultivated area of greater than 29 Million Hectares (Mha) with an average productivity of 841 kgha^{-1}. Andhra Pradesh has an area of 3.81 Lakh ha under blackgram cultivation with contribution of 7.57%. (Pulses Revolution from Food to Nutritional Security, 2018).

Blackgram is a short duration pulse crop grows on the marginal lands with low inputs due to which it is affected by many abiotic and biotic stresses. Insect pests, viral diseases and fungal diseases are different biotic stresses and among them whitefly is the most important insect pest which transmits the viral disease yellow mosaic virus (YMV)

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which results in severe yield losses and often total failure of the crop, if the incidence occurs during early stages of crop growth. The incidence of YMV disease results in yellow mottled appearance of the leaf with chlorotic spots and patches on older leaves and the younger leaves show complete yellowing in case of susceptible genotypes; yellowing and chlorosis leads to reduction in the photosynthetic efficiency of the plant, thereby finally resulting in the reduction of 25 to 78% yield in Mothbean (Vir, 1984).

To overcome the problem of YMV, host plant resistance studies plays a prominent role in resisting the insect pest attack on the crop throughout its growth period. The morphological, physiological and biochemical traits such as sugar, phenols, tannins, trichome density and SCMR values play a pivotal role in host plant resistance. In view of the above, an experiment has been conducted to study the host plant and insect interactions through the variability in the morpho-physiological and biochemical traits that influence the YMV disease resistance in blackgram varieties.

MATERIALS AND METHODS

A field experiment was conducted during *rabi* 2017-18 and 2018-19 at RARS Lam Guntur in a randomized block design with eight blackgram varieties and replicated thrice under receding soil moisture condition. Experiment was conducted using eight varieties of blackgram (LBG 787, GBG 1, TBG 104, LBG 884, LBG 806, LBG 808, LBG 623 and LBG 752) obtained from RARS, Lam, Guntur. The plot size was 4 rows with 4 meter length and sown with a spacing of 30x10 cm. The estimation of sugars, phenols, tannins, trichome density and SCMR was done at vegetative (30 DAS) and reproductive stages (50 DAS) of crop growth. The SCMR value was measured using Minolta SPAD-502 Chlorophyll meter. The seed yield was recorded at maturity. The experimental data was statistically analyzed using "Statistical Software Package for Agricultural Research Workers" (Sheoran *et al.,* 1998).

Trichome density

The trifoliate leaves from ten randomly selected plants of a plot were brought from the field and were cut into leaf discs of 1 cm diameter. These discs were observed under a stereo microscope to count the number of hairs present on the leaf disc and the average value of the trichome density was calculated as cm^2 leaf area.

SPAD chlorophyll meter reading (SCMR)

The SPAD meter reading was recorded from ten randomly selected plants within the plot. The most exposed leaf was preferred to record the SCMR value.

Total sugars (mg g^{-1} FW)

Total sugar content was estimated using anthrone reagent method (Hedge and Hofreiter, 1962). Fresh leaf sample of 0.25 g was ground in 5 ml of 70% hot ethanol and centrifuged at 5000 rpm for 15 min. Then the supernatant was discarded and the pellet was air dried. After air drying 5 ml of anthrone reagent (2 g of anthrone in 1 l 10:4 v/v Conc.H_2SO_4) was added to the pellet and the tubes were kept in ice bath at 4°C for 10 min and immediately the tubes were transferred to water bath at 80°C for 30 min. Later, the tubes were cooled to room temperature and the absorbance was read at 620 nm. A series of standards were prepared using fructose (1 mg per 10 ml) stock solution.

Total sugars (mg/ g FW of leaf) =

$$\frac{\text{Concentration} \times \text{Qty of extract prepared}}{1000 \times \text{weight of the sample}}$$

Phenols (mgg^{-1} FW)

Leaf Phenol content was estimated (Malik and Singh, 1980) using folin's reagent in which 0.25 g of fresh leaf was ground in 5 ml of 80% ethanol and kept it for 1 hour. 1 ml of aliquot was collected and 2 ml of 1 M sodium carbonate (10.6 g in 100 ml distilled water) was added. Later, 1 ml of folin reagent (1:9 v/v with water) was added and the tubes were kept in water bath for 20 min at 70°C. The absorbance was measured at 765 nm. Standard stock was prepared by using 0.5 g gallic acid in 10 ml ethanol and 90 ml of water and series of different concentrations as standards were made.

Total phenols (mg/ g fresh wt of leaf) =

$$\frac{\text{Concentration} \times \text{Qty of extract prepared}}{1000 \times \text{weight of the sample}}$$

Tannins (mg g^{-1} DW)

A powdered dry leaf sample of 0.5g was taken in test tube and 7.5 ml of water was added to it. The test tubes were kept in boiling water bath of 100°c for 30 min. The contents were centrifuged at 10,000 rpm for 20 min and the supernatant was collected. The volume was made to 10 ml with water. The extract obtained was used for assay with Folin-Denis' reagent by adding 0.5 ml of the reagent to the 0.1 ml of plant extract and also added 1 ml of 35% sodium carbonate solution and shaken well kept at room temperature for 30 min to take the readings at 700nm. A set of standard solutions were made of tannic acid (10, 20, 30, 40, 50 ìgml^{-1}) and the tannins content of the samples was expressed in mgg^{-1} dry weight of the sample (Sadasivam and Manickam ,1992).

Disease score

It is natural disease appearing during crop season. The plot wise symptoms on the plants were observed and per cent incidence of the disease was calculated by dividing the number of infected plants by total plant population of the plot and multiplied by hundred. Disease scoring was given based on formula given by Alice and Natarajan, (2007).

Disease scoring scale (0-9) for YMV based on Percentage disease incidence (PDI).

Disease Scale	Percent Infection	Category	Reaction group
1	No plants showing any symptoms	Free	
2	Small specks of 0.1 to 5% leaf area spread	Highly resistant	HR
3	Mottling of leaves of 5.1-10% leaf area	Resistant	R
4	Yellow mottling covering 10.1 – 15% leaf area	Moderately resistant	MR
5	Yellow mottling and discolouration of 15.1-20% leaf area	Moderately susceptible	MS
6	Yellow colouration of 20.1-30% leaves and pods	Susceptible	S
7	Pronounced yellow mottling and discolouration of 30.1-50% of foliage	Susceptible	S
8	Severe yellow discolouration of leaves 50.1-75% of foliage, stunted growth and reduction in pod size	Highly susceptible	HS
9	Severe yellowing of leaves covering above 75% foliage, stunting of plants and no pod formation	Highly susceptible	HS

RESULTS AND DISCUSSION

Sugars

The sugar content of the leaves of blackgram varieties was estimated by anthrone method and the values are given in Table 1. A significant difference was observed for total sugars among the varieties at vegetative and reproductive stages during both *rabi* 2017-18 and 2018-19. The leaf total sugar content decreased from vegetative stage to flowering stage in all genotypes in both the years. At vegetative stage during *rabi* 2017-18, higher total sugar content was recorded in the variety LBG 623 (47.78 mgg^{-1} FW) followed by LBG 787 (46.31 mgg^{-1}FW) and LBG 752 (45.16 mgg^{-1}FW) and are at par with each other and the lowest sugar content was recorded in the variety LBG 884 (35.50 mgg^{-1} FW) preceded by GBG 1 (40.77 mgg^{-1} FW). At reproductive stage during rabi 2017-18, highest sugar content was recorded in variety LBG 623 (39.36 mgg^{-1} FW) followed by LBG 787 (37.20 mgg^{-1} FW) and LBG 752 (36.34 mgg^{-1}FW) which are significantly higher than the other varieties and are at par with each other and the lowest sugar content was recorded in the variety LBG 884 (25.16 mgg^{-1}FW) preceded by GBG 1 (30.42 mgg^{-1} FW).

At vegetative stage during *rabi* 2018-19 higher sugar content was recorded in the varieties LBG 623 (49.82 mgg^{-1} FW) followed by LBG 787 (48.36 mgg^{-1}FW) and LBG 752 (47.21 mgg^{-1} FW) and are at par with one another and the lowest sugar content was recorded in the variety LBG 884 (38.55 $mmgg^{-1}$FW) preceded by GBG 1 (42.83 mgg^{-1}FW). At reproductive stage the leaf sugar content of the blackgram varieties followed the trend that was observed earlier with higher sugar content in the variety LBG 623 (41.41 mgg^{-1} FW) and the lower sugar content was record in the variety LBG 884 (27.21 mgg^{-1} FW).

The leaf total sugar content decreased from vegetative stage to reproductive stage in all the blackgram varieties tested and the variety with higher total sugar content showed high YMV incidence with reduced yield, whereas, the variety with lower total sugar content recorded higher yields with lower YMV disease incidence. The increase in the total sugar content of the leaves was observed to increase the susceptibility of the host plant to YMV. The total sugar content of the plants contributes as a nutritious diet to whitefly, insect vector that transmits the YMV disease. From the correlation studies it is evident that the total sugar content of the plants has a significant positive association with the whitefly population (Table 8). The increased total sugar content after YMV infection in the blackgram varieties increased the whiteflies populations especially on susceptible varieties. The increased whitefly populations increase the disease incidence on the susceptible varieties. The sugar contents, especially non reducing sugar acts as a good nutrient source to the whitefly population on blackgram, thereby increasing the whitefly population significantly to spread of YMV disease which shows the higher disease incidence percentage in the genotypes with higher leaf total sugar content (Gurumurthy *et al.* 2019). The rapid accumulation of total sugar in the susceptible genotypes increase the susceptibility further and also increase the rate of transmission of YMV. The accumulation of total sugar was observed to be lower in the resistant genotypes which reduce the whitefly preference and less disease incidence was observed in such genotypes. These results are in line with the findings of Ashfaq *et al.* (2014), Rajitha *et al.,* (2018) and Vannirajan *et al.* (2019) in blackgram

Phenolic content

A significant variation was observed among the varieties tested for leaf total phenolic content at vegetative and reproductive stages during *rabi* 2017-18 and 2018-19 (Table 2). The leaf total phenolic content increased from vegetative stage to flowering stage in all genotypes in both the years The leaf total phenols content is indispensable for the host plant resistance towards pest which acts as an anti-feedant that makes the pest to not show any propinquity towards the genotypes with higher total phenols contents. The leaf phenolic content at vegetative stage during *rabi* 2017-18 was observed to be higher in the variety LBG 884 (19.38 mg g^{-1} FW) followed by GBG 1 (17.66 mg g^{-1} FW) and TBG 104 (17.08 mg g^{-1} FW) which are in line with one another. The lowest phenolic content was recorded in the variety LBG 623 (10.26 mg g^{-1}FW). At reproductive stage during *rabi* 2017-18 highest phenolic content was recorded in the variety LBG 884 (22.50 mg g^{-1} FW) followed by GBG 1 (20.70 mg g^{-1}FW) and TBG 104 (20.20 mg g^{-1}FW).

At vegetative stage during *rabi* 2018-19, higher phenolic content was recorded in the variety LBG 884 (20.42 mg g^{-1} FW) followed by GBG 1(18.70 mg g^{-1} FW) and TBG 104 (18.13 g g^{-1} FW) and which are on par with each other and lowest phenolic content was recorded in the variety LBG 623 (11.31 mg g^{-1}FW) followed by LBG 787 (12.31 mg g^{-1} FW). At reproductive stage during *rabi* 2018-19 the highest phenolic content was recorded in the variety LBG 884 (23.55 mg g^{-1} FW) followed by TBG 104 (22.25 mg g^{-1} FW) and GBG 1(21.75 mg g^{-1} FW). The lowest phenolic content was recorded in the variety LBG 623 (14.18 mg g^{-1}FW) followed by LBG 787(15.19 mg g^{-1}FW) and LBG 752(15.55 mg g^{-1} FW).

The rapid accumulation of phenolic compounds immediately after the whitefly infestation in resistant genotypes is the most common adaptive response of resistant genotypes. In blackgram genotypes phytic acid accumulation was also observed along with the phenolic compound accumulation. Accumulation of phenols acts as the precursors for the formation of highly toxic quinines and other substances that determine the whitefly population in those genotypes. The total phenols content not only imparts the antibiosis resistant to whitefly but also acts as a trigger to the anti-oxidative response of plant to the virus infection. A significantly higher phenolic content was observed in the leaves of varieties that showed lower disease incidence under field conditions indicating the importance of phenolic content for YMV resistance. The phenolic compounds have attributed to the resistance of host plant towards the whitefly as the toxic nature of phenol causes damage to the insect. Further, phenolic compounds are capable of increasing the anti-oxidant enzyme activities such as phenyl alanine lyases and trigger the antioxidant activities of catalase and peroxidase. These compounds also directly act as activators of protective enzymes like polyphenol oxidases. In the current study, it was observed that the genotypes with high phenols content showed less incidence of YMV and the above results were corroborated with the studies of Tamilzharasi *et al.* (2020), Rajitha *et al.* (2018) and Vannirajan *et al.* (2019) in blackgram.

Tannin

The tannin content of the dried leaf samples was measured at vegetative and reproductive stages during both *rabi* 2017-18 and 2018-19 and the mean values were tabulated in Table 3 in mgg^{-1}DW and a significant variation was observed among the varieties tested. The tannins content increased from vegetative stage to flowering stage in all genotypes in both the years. The tannins content at vegetative stage during *rabi* 2017-18 was observed to be higher in the variety LBG 884 (0.047 mg g^{-1} DW) followed by GBG 1 (0.040 mg

Table 1: Sugar content of blackgram varieties as affected by YMV disease during *rabi* 2017-18 and 2018-19.

Genotypes	Sugar (mg g^{-1} FW)			
	2017-18		2018-19	
	30 DAS	50 DAS	30 DAS	50 DAS
LBG 787	46.31	37.20	48.36	39.25
GBG 1	40.77	30.42	42.83	32.47
TBG 104	41.13	32.49	43.18	34.54
LBG 884	35.50	25.16	38.55	27.21
LBG 806	44.63	34.74	46.68	36.79
LBG 808	42.89	33.16	44.94	35.21
LBG 623	47.78	39.36	49.82	41.41
LBG 752	45.16	36.34	47.21	38.39
CD at 5%	2.2	4.3	2.1	4.2
CV%	6,5	8.78	6.4	8.8

Table 2: Phenols content of blackgram varieties as affected by YMV disease during *abi* 2017-18 and 2018-19.

Genotypes	Phenols (mg g^{-1} FW)			
	2017-18		2018-19	
	30 DAS	50 DAS	30 DAS	50 DAS
LBG 787	11.26	14.14	12.31	15.19
GBG 1	17.66	20.70	18.70	21.75
TBG 104	17.08	20.20	18.13	22.25
LBG 884	19.38	22.50	20.42	23.55
LBG 806	12.60	15.60	13.65	16.65
LBG 808	13.19	19.53	13.24	20.58
LBG 623	10.26	13.13	11.31	14.18
LBG 752	11.40	14.50	12.45	15.55
CD at 5%	3.3	2.1	3.2	2.1
CV%	7.4	6.4.	7.4	6.5

Table 3: Tannins content of blackgram varieties as affected by YMV disease during *rab* 2017-18 and 2018-19.

Genotypes	Tannins (mgg^{-1} DW)			
	2017-18		2018-19	
	30 DAS	50 DAS	30 DAS	50 DAS
LBG787	0.020	0.035	0.018	0.033
GBG1	0.040	0.040	0.038	0.038
TBG104	0.035	0.041	0.033	0.039
LBG884	0.047	0.052	0.045	0.050
LBG806	0.030	0.035	0.028	0.033
LBG808	0.034	0.038	0.032	0.036
LBG623	0.016	0.027	0.014	0.025
LBG752	0.028	0.032	0.026	0.030
CD at 5%	0.009	0.008	0.008	0.007
CV%	14.6	16.50	13.6	15.50
CV%	16.50	14.6	15.50	13.6

g^{-1}DW) and TBG 104 (0.035 mg g^{-1} DW) which are on par with each another. The lowest tannins content was recorded in the variety LBG 623 (0.016 mg g^{-1} DW) followed by LBG 787(0.020 mg g^{-1} DW). At reproductive stage during *rabi* 2017-18 highest tannins content was recorded in the variety LBG 884 (0.052 mg g^{-1} DW) followed by TBG 104 (0.041 mg g^{-1}DW) and GBG1 (0.040 mg g^{-1} DW). The lowest tannins content was recorded in the variety LBG 623 (0.027 mg g^{-1} DW) followed by LBG 752(0.032 mg g^{-1} DW).

At vegetative stage during *rabi* 2018-19, higher tannins content was recorded in the variety LBG 884 (0.045 mg g^{-1} DW) followed by GBG 1(0.038 mg g^{-1}DW) and TBG 104 (0.033 g g^{-1}DW) and are on par with each other and lowest tannins content was recorded in the variety LBG 623 (0.014 mg g^{-1} DW) followed by LBG 787 (0.018 mg g^{-1} DW). At reproductive stage during *rabi* 2018-19 the highest tannins content was recorded in the variety LBG 884 (0.050 mg g^{-1} DW) followed by TBG 104 (0.039 mg g^{-1} DW) and GBG 1(0.038 mg g^{-1} DW). The lowest tannins content was recorded in the variety LBG 623 (0.025 mg g^{-1}DW) followed by LBG 752(0.030 mg g^{-1} FW).

The tannins are a group of phenolic compounds which are known for their astringent nature and protect the plant from insect pests through antibiosis. The tannins are of two types present in the plants those are of condensed tannins and hydrolysable tannins. Condensed tannins are the type of tannins that are involved in imparting resistance against aphids and whitefly. The astringent nature of the condensed tannins imparts anti-feedant character to the leaves of resistant genotypes. The higher tannins content values are recorded in the varieties with lower disease score. The tannins content has significantly affected the vector population which has reduced the per cent disease incidence. The tannins production along with the pigmentation has influence on host plant resistance (Davies, 2004). A significant higher tannins and flavonoids content were observed in the YMV resistant varieties of blackgram (Taggar *et al.*, 2014). In this study, tannins content in the dried leaves of blackgram genotypes showed that higher the tannin content lesser the whitefly incidence and the similar results were reported by Taggar *et al.* (2014) in blackgram.

Trichome density

The trichome density of the ten randomly selected most exposed leaves from each plot were taken and the average number of trichomes was calculated per cm^2 and the values were enumerated in Table 4. The trichome density values indicate the average number of trichomes per cm^2 of the leaf lamina. The pubescence of the leaf plays an important role in repelling the pests.

At vegetative stage during *rabi* 2017-18 the higher trichome density was recorded in the variety LBG 884 (74.59/ cm^2 of leaf area) (Plate 1A) followed by GBG 1 (72.52/cm^2 of leaf area) and TBG 104 (68.40/cm^2 of leaf area) and the lower trichome density was observed in the variety LBG 623 (20.43/cm^2 of leaf area) followed by LBG 787 (48.06/cm^2 of leaf area). At reproductive stage during *rabi* 2017-18 the highest trichome density was recorded in the variety LBG 884(67.82/cm^2 of leaf area) followed by GBG 1 (65.00/cm^2 leaf area) amd TBG 104(61.51/cm^2 leaf area) and the lowest trichome density was recorded in the variety LBG 623 (14.86/cm^2 of leaf area) followed by LBG 787(41.40/cm^2 of leaf area).

At vegetative stage during *rabi* 2018-19 the highest trichome density was recorded in the variety LBG 884 (72.64/ cm^2 of leaf area) followed by GBG 1 (70.57/cm^2 of leaf area)

Table 4: Trichomes density of blackgram varieties as affected by YMV disease during *rabi* 2017-18 and 2018-19.

Genotypes	Trichome density (Trichome number cm^{-2})			
	2017-18		2018-19	
	30 DAS	50 DAS	30 DAS	50 DAS
LBG 787	48.06	41.40	46.10	39.45
GBG 1	72.52	65.00	70.57	63.05
TBG 104	68.40	61.51	66.45	59.56
LBG 884	74.59	67.82	72.64	65.87
LBG 806	55.63	48.60	53.68	46.65
LBG 808	60.45	53.54	58.50	51.59
LBG 623	20.43	14.86	18.48	12.91
LBG 752	51.50	44.00	49.55	42.05
CD at 5%	18.01	11.23	8.01	9.23
CV%	18.20	12.46	16.20	12.41

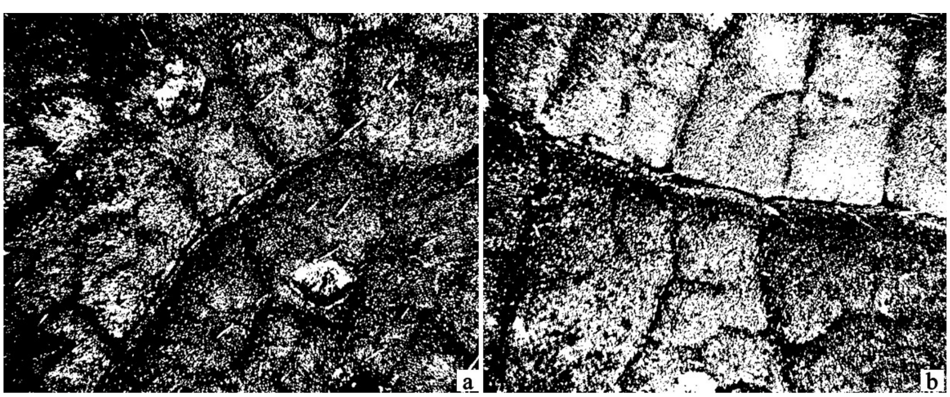

Plate 1: Variation in trichome density of varieties LBG 884 (a) and LBG 623 (b) at 4x optical zoom.

and TBG 104 (66.45/cm^2 of leaf area). The lowest trichome density was observed in the variety LBG 623 (18.48/cm^2 of leaf area) (Plate 1B) followed by LBG 787(46.10 /cm^2 of leaf area). At reproductive stage during rabi 2018-19 the highest trichome density was recorded in the variety LBG 884 (65.87/cm^2 of leaf area) followed by GBG 1 (63.05/ cm^2 leaf area) and TBG 104 (59.56/cm^2 leaf area) the lowest was recorded in the variety LBG 623 (12.91/cm^2 of leaf area) followed by LBG 787(39.45 /cm^2 of leaf area).

Variations in trichome density of LBG 884 and LBG 623 are depicted in Plate 1. The trichome density showed a significant effect on whitefly population in blackgram varieties. This trichome density plays an important role as a morphological anti-feedant which reduces the pest attack and subsequently lowers the disease incidence and the plants with high trichome density showed less YMV symptoms. The higher trichome density hinders the free movement of white fly nymphs and adults making the genotypes with higher trichome density less preferable.The resistant varieties showed higher values of trichome density The study was emphasized on trichome density which showed that the genotypes with high trichome density was less effected by YMV in blackgram (Devi *et al.* 2019; Taggar and Gill, 2012; and Suman *et al.* 2018).

SCMR (SPAD Chlorophyll meter reading)

The SPAD Chlorophyll meter reading (SCMR) is the actual value of a factor representing the number of chlorophyll molecules present per unit leaf area (Table 5). In the present study, SCMR values varied significantly among the genotypes at different growth stages during both the seasons of *rabi* 2017-18 and 2018-19. All the genotypes showed an increase in the SCMR values from 30 DAS to 50 DAS.At vegetative stage during rabi 2017-18 the higher SCMR value (Table 5) was recorded in the variety LBG 884 (45.12) followed by GBG 1 (44.70) and TBG 104 (43.10) .The lower SCMR was observed in the variety LBG 623 (32.21) followed by LBG 787(40.65) .At reproductive stage during *rabi* 2017-18 the higher SCMR value was recorded in the variety LBG 884 (53.17) followed by GBG 1 (51.27) and TBG 104(50.27).The lower SCMR value was recorded in the variety LBG 623 (37.13) followed by LBG 787 (45.25).

At vegetative stage during *rabi* 2018-19 the higher SCMR value was recorded in the variety LBG 884 (47.12) followed by TBG 104 (45.10) and GBG 1(44.70) which are on par with each other. The lower SCMR value was observed in the variety LBG 623 (24.21) followed by LBG 787 (42.65). At reproductive stage during *rabi* 2018-19 the higher SCMR value was recorded in the variety LBG 884 (55.17) followed by GBG 1(53.27) and TBG 104 (52.27) which are at par with each other . The lower SCMR value was recorded in the variety LBG 623 (25.13) followed by LBG 787 (47.25).

The genotypes with darker leaves were less preferred by whiteflies. The SCMR value is a parameter that can be recorded easily with in the field and all the remaining morpho-physiological and biochemical parameters that impart resistance to YMV disease showed a highly significant correlation with SCMR. The above characteristic features of SCMR made it a dependable and easy screening technique for YMV resistant genotypes. SCMR gives the absorbance of chlorophyll molecules in the leaf tissue of specific area measured at Infrared and far infrared wavelengths which give the arbitrary value of chlorophyll content of that area. The chlorophyll content also affects the whitefly population and YMV disease, decreased chlorophyll values were recorded in susceptible genotypes. The genotypes with higher chlorophyll values showed tolerance to YMV disease; similar results were found by Rajitha *et al.* (2018). in blackgram

Disease score

The disease score values recorded at reproductive stage in all the genotypes showed observable variation among the varieties (Table 6). The varieties LBG 884, TBG 104 and GBG 1 showed a score of '2' during both *rabi* 2017-18 and 2018-19 which indicates highly resistant type. The varieties LBG 808 and LBG 806 showed a score of '3' during *rabi* 2018-19 and 2017-18 indicating resistant category. The variety LBG 752 showed a score of '4' during *rabi* 2017-18 and '4' during *rabi* 2018-19 indicating that, the variety LBG 752 was moderately resistant to YMV disease under field condition. The variety LBG 787 recorded scores of 5 and 5 during *rabi* 2017-18 and 2018-19 respectively falling under the category of moderately susceptible genotype. The variety LBG 623 showed a score of '9' during both *rabi* 2017-18 and 2018-19 showing highly susceptible nature. These results are in confirmation with the studies of Raj *et al*. (2019) in screening greengram varieties and Gopi *et al*. (2018), Devi *et al*. (2019) and Vannirajan *et al.* (2019) in screening of blackgram genotypes.

Yield

Higher seed yield was noticed in the variety LBG 884 (1191 and 1240 kg ha^{-1}) in both *rabi* 2017-18 and 2018-19 due to least YMV disease incidence followed by GBG 1 (1070 and

Table 5: SCMR and Seed yield of blackgram varieties as affected by YMV disease during *rabi* 2017-18 and 2018-19.

Genotypes	SPAD Chlorophyll meter reading (SCMR)			
	2017-18		2018-19	
	30 DAS	50 DAS	30 DAS	50 DAS
LBG 787	40.65	45.25	42.65	47.25
GBG 1	44.70	51.27	44.70	53.27
TBG 104	43.10	50.27	45.10	52.27
LBG 884	45.12	53.17	47.12	55.17
LBG 806	43.83	48.24	45.83	50.24
LBG 808	42.75	47.35	44.75	49.35
LBG 623	32.21	37.13	24.21	25.13
LBG 752	42.36	47.56	44.36	50.56
CD at 5%	3.51	3.3	2.91	2.8
CV%	16.5	14.32	15.5	15.32

Table 6: YMV disease score of blackgram varieties during *Rabi* 2017-18 and 2018-19.

Genotypes	Disease score (0-9)		Category	Reaction group
	2017-18	2018-19		
LBG 787	5	5	Moderately Susceptible	MS
GBG 1	2	2	Highly resistant	HR
TBG 104	2	2	Highly resistant	HR
LBG 884	2	2	Highly resistant	HR
LBG 806	3	4	Moderately resistant	MR
LBG 808	3	3	Resistant	R
LBG 623	9	9	Highly susceptible	HS
LBG 752	4	4	Moderately resistant	MR

Table 7: Seed yield of blackgram varieties as affected by YMV disease during Rai 2017-2018 and 2018-2019.

Genotypes	Seed yiel d (Kg/ha)	
	2017-18	2018-19
LBG 787	800	810
GBG 1	1070	1120
TBG 104	1010	1060
LBG 884	1191	1240
LBG 806	900	950
LBG 808	950	1010
LBG 623	700	751
LBG 752	860	915
CD at 5%	174	150
CV%	10.70	11.70

Table 8: Correlation of the traits observed with disease score in blackgram varieties.

Trait name	Disease score
Sugar	0.89
Phenols	-0.94
Tannins	-0.92
Trichome density	-0.94
SPAD Chlorophyll meter reading (SCMR)	-0.78
Seed yield	-0.94

1120 kg ha^{-1}) and TBG 104 (1010 and 1060 kg ha^{-1}) in both the seasons (Table 7). The lower seed yield was observed in genotype LBG 623 (700 and 751 kg ha^{-1}) in both the seasons. The susceptible genotypes showed high YMV disease incidence with lower yields, whereas, the resistant genotypes recorded higher yields with less YMV incidence (Devi *et al*. 2019 and Subedi *et al.,* 2016).

Correlations

The correlation studies indicated that the disease score showed a highly significant negative correlation with phenols, tannins content, trichome density, SCMR and yield and a highly significant positive correlation with total sugars content (Table 8). Devi *et al*. (2019), Taggar and Gill (2012) Taggar *et al.* (2014) and Vannirajan *et al.* (2019) similar results were reported in blackgram.

CONCLUSION

From these results it can be inferred that the higher phenols, tannins content and trichome density and less sugar content traits contributed YMV resistance in LBG 884, GBG 1 and TBG 104 of blackgram. The varieties LBG 884, GBG 1 and TBG 104 were grouped under highly resistant category with higher phenols, tannins content and trichome density. The varieties LBG 806 and LBG 808 were categorized under resistant group. The variety LBG 752 was grouped under moderately resistant group. The variety LBG 787 and LBG 623 were grouped under moderately susceptible and highly susceptible category respectively with lower phenol and tannins and trichome density and higher sugar content.

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