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Research Paper

Effect of Yellow Mosaic Disease on Gas exchange parameters of Blackgram (*Vigna mungo* L. Hepper)

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Abstract:

A field experiment was conducted during Kharif 2018 at Botanical Garden of Acharya Nagarjuna University to determine the effect of Yellow mosaic virus infection on photosynthetic and yield attributes of Blackgram (Vigna mungo L.. Hepper). A total of fifty blackgram varieties were obtained from Regional Agricultural Research Station, Lam, Guntur, Andhra Pradesh. The obtained blackgram varieties were cultivated and left to infection of YMV. The data was collected on chlorophyll content, SCMR, photosynthetic rate, stomatal conductance, transpiration and yield per hectare. Of all the varieties Ku-15-9, TU-18 and PGRU-99-028 recorded high chlorophyll content coupled with high SCMR content and photosynthetic activity. Varieties Ku-15-9, TU-18 and PGRU-99-028 also reported high yield content per hectare 1685.45 q/h, 1595.00 q/h and 1280.00 q/h respectively. Based on the performance of the all the varieties, varieties Ku-15-9, TU-18 and PGRU-99-028 should be considered as resistant to yellow mosaic disease.

Keywords: Blackgram, YMV, SCMR, Yellow mosaic disease

1. Introduction

Many of the plant diseases are caused by viruses and are one of the key biotic stressors of the plants responsible for huge losses worldwide both qualitatively and quantitatively (Kang *et al*., 2005). The most common viral symptom is leaf chlorosis, results in altered pigmentation and structural change of chloroplasts. Loss of photosynthetic activity is evident in the appearance of macroscopic symptoms such as yellow or green mosaic patches or total reduction of chlorophyll. Mosaic diseases are known to be commonly associated with decreased photosynthesis, as a result of chlorophyll loss and consequently less organic carbon in the infected leaves (Matthews, 1991).

Viral influence on chloroplast structures and functions usually leads to decreased gas exchange activity (Christov *et al*., 2007; Zhao *et al*., 2016). It has been reported that the rate of photosynthesis expressed by CO_2 consumption was not altered by virus infection until symptoms appeared (Zaitlin and Hesketh, 1965). The disturbance of chloroplast components and functions may be responsible for the production of chlorosis symptoms that are associated with virus infection (Manfre *et al*., 2011). Viruses may interfere with photochemical reactions by depleting the availability of key proteins involved in the photosynthetic mechanism (Rodriguez *et al*., 2010). Effects of virus infection on photosynthesis are particularly important because they affect performance of the host plants directly through biomass production.

Decreased chlorophyll content during viral infection was previously reported by so many workers (Pawar *et al*., 1990; Muqit *et al*., 2007; Arora *et al*., 2009; Sinha and Srivastava, 2010). Loss of chlorophyll in infected leaves has been attributed to either impaired chlorophyll synthesis (Funayama-Noguchi and Terashima, 2006), structural alterations in the photosynthetic apparatus (Goncalves *et al*., 2005) or reduced activities of some enzymes associated with electron transport and photosynthesis (Zhou *et al*., 2004; Guo *et al*., 2005) as previously discussed.

Nitrogen is one of the basic components of nucleic acids, amino acids, proteins, enzymes and chlorophyll and the SCMR data gives the clear fate of leaf nitrogen content. Studies have shown positive correlation between leaf nitrogen content and the photosynthetic capability of leaves (Ripullone *et al*., 2003; Babu *et al*., 2009). According to Evans (1989), the proteins of the Calvin cycle and thylakoids represent the majority of leaf nitrogen and to a first approximation thylakoid nitrogen has been shown to be proportional to the chlorophyll content. Lee *et al*. (2011) have also shown a correlation between leaf nitrogen and chlorophyll content.

Based on the data, mechanisms of the decrease in photosynthetic rate by virus infection will be discussed. The most effective ways of managing viruses are cultural control and the use of tolerant cultivars. A better understanding of plant response to viral infection may lead to novel tools for effective plant protection.

Blackgram (*Vigna mungo* L. Hepper) is one of the important pulse crop belongs to the family leguminaceae and its cultivation is mainly confined to Indian subcontinent. In India it is cultivated in 32.60 lakh ha producing 17.60 lakh tons with an average productivity of 534 kg/ha (Project co-ordinates (MULLaRP) Report, IIPR, Kanpur 2011-12). In Andhra Pradesh blackgram is traditionally cultivated as a *rabi* pulse crop under rice fallows mainly along the coastal areas, in an area of 5 lakh ha

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with a production and productivity of 3.29 lakh tons and 728 kg/ha, respectively during 2016-17 (Bandi *et al*., 2018). The blackgram seeds are the good reservoirs of the proteins along with high availability of various B-Complex vitamins and prime elements such as potassium, iron and calcium (Wani *et al*., 2013; Babu and Rosaiah, 2016, 2017). The yellow mosaic virus is the most destructive viral disease of blackgram causing yield loss up to 85% (Varma and Malathi, 2003) or sometimes total failure of the crops. The symptom starts from the young leaves with small yellow patches on leaves and ends with complete yellowing of young leaves in susceptible genotypes (Singh and De, 2006). Evaluation of germplasm for disease resistance is an important step in controlling the diseases through host plant resistance. Studies on chlorophyll content and photosynthetic attributes may give a clear insight of the disease mechanism and will be useful in identifying the YMV resistant blackgram varieties. Hence, the present study has been taken up to evaluate germplasm of blackgram to withstand to the Yellow Mosaic Virus.

2. Methodology

A total of 50 blackgram varieties i.e PU 30, KU 15-19, KU 15-6, P 1070, LBG 777, LBG 775, P 205, SPS 26, KU 15-3, GKU 02-1, KU 15-14, T9, TU 18, TBG 104, PGRU 99-028, VH 85-5, UK 2289, PLU 10-4, LBG 783, KU 15-9, KU 708, KU 15-2, LBG 20, KU 15-10, LBG 752, LBG 708, KU 15-7, LBG 645, KU 15-20, CN 8072, P 726, IPU 10-4, RUG 44, CPS 35, LBG 788, KU 15-13, KU 323, P 728, KU 15-11, LBG 685, UTTARA, KU 15-4, PU 31, LBG 623, LBG 787, LBG 791, KU 15-16 and LBG 722 were obtained from Regional Agricultural Research Station (RARS), Lam, Guntur constitute the experimental material for the present study.

All the 50 entries were planted in 5 replicated rows arranged in a randomized block design and each row measures around 5 m length with arrow to row distance of 30 cm and plant to plant distance of 10 cm. Plots were regularly observed for good agronomic control and proper care was taken to protect from pests and birds. The data on various characters were collected from all the varieties with an interval of 15 days each and continued till to the day of harvest.

Leaf chlorophyll (mgg^{-1})

Total leaf chlorophyll of each variety was calculated by using DMSO method (Hiscox and Israelstam, 1979). According to this method 30 mg of fresh and dark green leaf material was taken into a test tube. To this test tube 10 ml of dimethyl sulfoxide (DMSO) was added and the entire set up was kept in hot water bath at 60 °C for about 30 minutes until the chlorophyll pigment was extracted into DMSO. The optical density was recorded at 645 and 663 nm by using UV–VIS spectrophotometer (Elico *SL 159*). The amount of chlorophyll pigment present in the sample was calculated by using the following formulae and was expressed as milligrams of chlorophyll per gram fresh weight (mgg^{-1} fr.wt).

$$\text{Total chlorophyll} = (20.2 \times \text{O.D at 645 nm} + 8.02 \times \text{O.D at 663 nm}) \times \frac{V}{10} \times W$$

SPAD Chlorophyll Meter Reading (SCMR)

The SCMR measurements were taken on five randomly selected plants by selecting third fully matured leaf from the apex of the stem of each plant (Kashiwagi *et al.*, 2010). SPAD-502 meter (Minolta Konica Co. Ltd., Japan) was used to measure the SCMR values.

Photosynthetic parameters

The parameters like photosynthetic rate (Pr), stomatal conductance (Gs), and transpiration rate (T) were measured by using Licor–*Li 6400 XT* portable photosynthetic system. The above were expressed in units viz., µmol of CO_2 fixed per $m^{-2}s^{-1}$, mol of gas evolved per $m^{-2}s^{-1}$, µ mol mol^{-1} CO_2 and mmol of water released per $m^{-2}s^{-1}$.

Yield/hectare (Kgh^{-1})

Yield per hectare was measured by using the following formula.

$$\text{Yield/hectare} = \frac{\text{Total yield}}{\text{Plot area}} \times 10000$$

Where plot area is 5.0 m^2

YMV screening parameters

The disease was scored on a 1-9 arbitrary scale according to Alice and Nadarajan (2007).

Rating scale for scoring yellow mosaic virus disease (1-9 scale):

No visible symptoms on leaves or very minute yellow specks on leaves. 2. Small yellow specks with restricted spread covering 0.1 to 5 % leaf area. 3. Yellow mottling of leaves covering 5.1 to 10 % leaf area. 4. Yellow mottling of leaves covering 10.1 to 15 % leaf area.

Yellow mottling and discoloration of 15.1 to 30 % leaf area. 6. Yellow discoloration of 30.1 to 50 % leaf area. 7. Pronounced yellow mottling and discoloration of leaves and pods, reduction in leaf size and stunting of plants covering 50.1 to 75

% foliage. 8. Severe yellow discoloration of leaves covering 75.1 to 90 % of foliage, stunting of plants and reduction in pod size. 9. Severe yellow discoloration of entire leaves covering above 90.1 % of foliage, stunting of plants and no pod formation.

Observations on the disease incidence were taken on randomly selected five plants of each entry and took a mean of each entry to assign the category. The following categories are used in assessing the resistant reaction for yellow mosaic virus disease.

Rating	Reaction
Resistant (R)	1.0 to 2.0
Moderately resistant (MR)	2.1 to 4.0
Moderately susceptible (MS)	4.1 to 5.0
Susceptible (S)	5.1 to 7.0
Highly susceptible (HS)	7.1 to 9.0

Analysis of variance (ANOVA) test appropriate to the random block design (RBD) was carried out using AGRISTAT software. Correlation coefficients between traits were calculated by using MINITAB 16 software.

3. Results

A field experiment comprising of 50 blackgram genotypes was carried out in a completely randomized block design with all recommended agronomic practices during *kharif* 2016 for screening of blackgram cultivars against yellow mosaic disease at field level (Plate 1).

Plate 1. Field trials of 50 blackgram genotypes against yellow mosaic disease

Total chlorophyll (mgg^{-1})

Amount of chlorophyll present in the healthy and infected plants was recorded and it was varied significantly both in normal and YMV infected plants. The total chlorophyll content was ranged from1.10 mgg^{-1} to 2.99 mgg^{-1} in healthy plants and from 0.89 mgg^{-1} to 2.92 mgg^{-1} in YMV infected plants (Table 1). The genotypes KU 15-9 (2.99 mgg^{-1}), PGRU 99-028 (2.84 mgg^{-1}), TU 18 (2.80 mgg^{-1}) and KU 15-6 (2.68 mgg^{-1}) were showed highest chlorophyll content in healthy and YMV infected plants KU 15-9 (2.92 mgg^{-1}), TU 18 (2.78 mgg^{-1}), PGRU 99-028 (2.76 mgg^{-1}) and KU 15-6 (2.57 mgg^{-1}).

SCMR

The SPAD chlorophyll meter reading was measured (Table 11). It was varied from 23.66 (LBG 645) to 43.46 (KU-15-9) in healthy plants and 20.20 (LBG 685) to 42.76 (KU-15-9) in infected plants with a mean value of 35.94 and 29.50 respectively. The varieties LBG 645 (23.66) recorded less SCMR values in case of healthy cultivars. The high SCMR values were found to be recorded in healthy plants KU-15-9 (43.46) followed by PGRU 99-028 (43.36), KU-15-6 (42.33) and LBG 709 (41.46). The highest SCMR values were recorded with KU-15-9 (42.76) followed by TU-18 (40.20) and KU-15-6 (39.17) in YMV infected plants.

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Photosynthetic rate (µmole/sqcm)

The rate of photosynthesis was varied significantly in all the genotypes both in healthy and YMV infected plants (Table 2). Photosynthetic rate was varied between 7.27 µmole/sqcm to 27.65 µmole/sqcm in normal plants and it is between 2.34 µmole/sqcm to 25.89 µmole/sqcm in YMV infected plants. In both healthy and infected plants highest photosynthetic rate (A) was recorded in KU 15-9 (Healthy 27.65 µmole/sqcm; YMV infected 24.225.89 µmole/sqcm), PGRU 99-028 (Healthy 21.95 µmole/sqcm; YMV infected 19.84 µmole/sqcm), TU 18 (Healthy 18.60 µmole/sqcm; YMV infected 17.19 µmole/sqcm) and KU 15-6 (Healthy 18.72 µmole/sqcm; YMV infected 17.00 µmole/sqcm).

Stomatal conductance (mmole/sqcm)

Stomatal conductance was also varied significantly in all the genotypes in healthy and infected plants. Stomatal conductance was ranged between 0.08 mmole/sqcm to 0.33 mmole/sqcm in healthy plants and 0.03 mmole/sqcm to 0.26 mmole/sqcm in infected plants (Table 2). Maximum stomatal conductance was observed in KU 15-2 (0.33 mmole/sqcm) followed by LBG 20, T9 (0.32 mmole/sqcm), LBG 645 (0.30 mmole/sqcm) where as in case of YMV effected plants stomatal conductance was recorded in TU 18, PGRU 99-028 (0.26 mmole/sqcm), KU 15-9 (0.25 mmole/sqcm) and KU 15-6 (0.24 mmole/sqcm).

Transpiration rate (mol m^{-2} s^{-1})

Rate of transpiration was also varied significantly in all the genotypes. The transpiration was ranged from 2.64 mol m^{-2} s^{-1} to 5.89 mol m^{-2} s^{-1} in healthy plants and in case of YMV infected plant it was varied between 1.10 mol m^{-2} s^{-1} to 5.50 mol m^{-2} s^{-1} (Table 2). Among the healthy plants highest transpiration was observed in KU 15-9 (5.89 mol m^{-2} s^{-1}), KU 15-6 (5.42 mol m^{-2} s^{-1}), PGRU 99-028 (5.36 mol m^{-2} s^{-1}) and TU 18 (5.32 mol m^{-2} s^{-1}). Reduction in transpiration rate was varied significantly in all the infected plants. But the varieties such as KU 15-9 (5.50 mol m^{-2} s^{-1}), KU 15-6 (5.00 mol m^{-2} s^{-1}), TU 18 (4.89 mol m^{-2} s^{-1}) and PGRU 99-028 (4.12 mol m^{-2} s^{-1}) were maintained high transpiration rate even under high biotic stress.

Yield per hectare (Kgh^{-1})

The effect of yellow mosaic virus on yield was calculated and it is found to be reduced drastically in all the infected plants. Among all the fifty varieties yield per hectare was calculated and it was ranged from 386.88 kgh^{-1} to 1719.75 kgh^{-1} in healthy plants whereas in case of YMV infected plants yield per hectare was ranged from 200.40 kgh^{-1} to 1685.00 kgh^{-1} (Table 3). Of all the genotypes maximum yield per hectare was reported in varieties such as KU 15-9 (1719.75 kgh^{-1}), TU 18 (1605.63 kgh^{-1}), PGRU 99-028 (1316.20 kgh^{-1}) and KU 15-6 (1281.88 kgh^{-1}). In case of diseased plants also maximum yield per hectare was reported by the KU 15-9 (1685.45 kgh^{-1}), TU 18 (1595.00 kgh^{-1}), PGRU 99-028 (1280.00 kgh^{-1}) and KU 15-6 (1200.00 kgh^{-1}).

Percent infection per plant (%)

Percent infection per plant was measured in order to identify the damage to the plant due to YMV infection. All the genotypes were prone to infection but the severity of infection was varied from genotype to genotype (Table 4). Among all the plants the maximum infection of 95.12% was observed in genotype LBG 722 followed by LBG 788 (81.89%) and T9 (80.00%) where as the lowest infection observed in TU 1 (10.29%) followed by KU 15-6 (10.57%), PGRU 99-028 (10.81%) and KU 15-9 (10.96%).

Disease scoring scale

1-9 disease scoring scale was applied to know the severity of infection (Table 4). Among all the 50 genotypes 4 varieties (KU 15-6, TU 18, PGRU 99-028 and KU 15-9) were came under scale 1. Varieties such as UK 2289, LBG 709, KU 15-7, KU 15-16 came under scale 2. Genotypes came under scale 3 are P 205, GKU 02-1, KU 15-14, KU 323. Twelve varieties (PU 30, LBG 775, KU 15-3, VH 85-5, KU 15-2, LBG 20, LBG 752, KU 15-20, P 726, KU 15-13, UTTARA and LBG 623came under scale 4. Varieties i.e PLU 10-4, LBG 783, IPU 10-4 and KU 15-4 came under scale 5. The genotypes such as KU 15-19, KU 708, LBG 708, CN 8072, KU 15-11 and LBG 787 came under scale 6. Five varieties P 1070, LBG 777, SPS 26, KU 15-15, KU 15-10 and RUG 44 came under scale 7. Genotypes viz., T9, TBG 104, LBG 645, CPS 35, LBG 788, P 728, LBG 685, PU 31 and LBG 791 were came under scale 8 and only one variety came under scale 9 is LBG 722.

Grouping of genotypes screened against YMV

Grouping of blackgram genotypes against YMV was done using 1-9 arbitrary scale (Table 5). Varieties KU 15-6, TU 18, PGRU 99-028 and KU 15-9, UK 2289, LBG 709, KU 15-7 and KU 15-16 came under resistant (R) genotypes against YMV (1.0 to 2.0 rating). Blackgram genotypes such as P 205, GKU 02-1, KU 15-14, KU 323, PU 30, LBG 775, KU 15-3, VH 85-5, KU 15-2, LBG 20, LBG 752, KU 15-20, P 726, KU 15-13, UTTARA and LBG 623 came under 2.1 to 4.0 rating which are moderately resistant (MR). Varieties i.e PLU 10-4, LBG 783, IPU 10-4 and KU 15-4 came under scale 4.1 to 5.0 rating which is moderately susceptible (MS). The genotypes such as KU 15-19, KU 708, LBG 708, CN 8072, KU 15-11 and LBG 787, P 1070, LBG 777, SPS 26, KU 15-15, KU 15-10 and RUG 44 came under scale 5.1 to 7.0 rating and are susceptible (S). Genotypes viz., T9, TBG 104, LBG 645, CPS 35, LBG 788, P 728, LBG 685, PU 31, LBG 791 and LBG 722 came under 7.1 to 9.0 rating and are highly susceptible (HS).

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4. Discussion

Yellow mosaic virus infection causes around 5-90% yield loss in blackgram. The major reason for this is reduced chlorophyll content and there by photosynthetic activity. The reduced chlorophyll content is may be due to the altered chloroplast structure and function (Zhao *et al*., 2016). The interaction between chloroplast and the invading virus plays a critical role in viral infection and pathogenesis (Zhao *et al*., 2016). In present study germplasm KU-15-9 and PGRU-99-028 recorded high chlorophyll content coupled with nitrogen and photosynthetic rate. The maintaining of stabilized photosynthetic rate is may be due to their inherent ability. Previous works on virus interaction with chloroplast had reveal that viruses can interrupt the chloroplast proteins and alter the formation of membrane vesicles during viral replication, which impairs chloroplast functions in plants (Liu *et al*., 2014; *Li et al*., 2016a).

Gas exchange performance also indicates that CO_2 assimilation may have been altered by virus infection. As blackgram is a C_3 plant it cannot assimilate the CO_2 with high efficiency and there impacts the availability of CO_2 (Salisbury and Ross, 1992). Several photosynthetic enzymes depend on light and energy as ATP and NADPH for CO2 assimilation and reduction are found to be less abundant in infected cells due to virus infection and its growth. Even at these worst conditions KU-15-9 and PGRU-99-028 tend to stabilize their photosynthetic enzymes and results in high yields in these varieties (Table 1). This study brings insights to the direct effects of viral infection on chlorophyll content and photosynthetic enzymes. Apart from this the effect of YMV on yield attributes was also understood.

5. Conclusion

On the basis analyzed results and disease scoring scale (Table 2 and Table 3) it is concluded that genotypes such as KU 15-6, KU-15-9, TU 18, PGRU 99-028 found to be relatively more resistant to yellow mosaic disease during *kharif* season and these can be useful in developing YMV resistant blackgram varieties.

6. Acknowledgements

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Table 1. Variations in photosynthetic and yield attributes both in healthy and yellow mosaic virus infected genotypes

Sr. No.	Character → / Variety↓	Total chlorophyll (mg/g)		SCMR		Photosynthetic rate (µmole/sqcm)		Stomatal conductance (mmole/sqcm)		Transpiration rate (mol m^{-2} s^{-1})		Yield/acre (Kgh^{-1})	
		Healthy	Infected	Healthy	Infected	Healthy	Infected	Healthy	Infected	Healthy	Infected	Healthy	Infected
1	PU 30	1.99*	1.62	33.66	27.24	16.75	9.20	0.22	0.09	4.62	2.19	993.10*	673.00
2	KU 15-19	1.72	1.30	36.44	30.12	23.30*	6.89	0.27*	0.12	5.24	3.27	674.94	480.42
3	KU 15-6	2.68*	2.57*	42.33*	39.17*	18.72*	17.00*	0.27*	0.24*	5.42*	5.00*	1281.88*	1200.00*
4	P 1070	1.70	1.36	32.33	25.12	15.77	6.18	0.26*	0.14	5.24	3.12	740.74	360.00
5	LBG 777	1.54	1.08	37.47	30.12	16.15	8.91	0.27*	0.19	5.28*	3.71*	495.26	310.20
6	LBG 775	2.14*	1.49	40.98*	36.00*	20.52*	9.16	0.25	0.17	5.08	3.01	1020.38*	625.16
7	P 205	2.34*	1.52	40.84*	36.92*	16.36	8.28	0.28*	0.21	5.22	3.14	1117.66*	700.25*
8	SPS 26	1.91	1.10	40.29*	34.20	14.34	9.16	0.23	0.16	4.65	2.10	285.95	300.00
9	KU 15-3	1.89	1.56	39.69	32.97	14.23	9.37	0.18	0.09	3.99	2.21	974.73*	680.00*
10	GKU 02-1	1.79	1.52	40.46*	33.00	17.80*	8.32	0.24	0.15	4.69	2.71	910.79*	720.25*
11	KU 15-14	1.86	1.61	36.48	29.82	15.75	9.06	0.24	0.17	4.48	2.24	988.24*	700.19*
12	T 9	1.10	0.89	39.03	31.15	16.09	9.27	0.32*	0.14	5.31*	2.87	519.46	250.56
13	TU 18	2.80*	2.78*	42.58	40.20*	18.60*	17.19*	0.28*	0.26*	5.32*	4.89*	1605.63*	1595.00*
14	TBG 104	1.20	1.49	31.54	24.21	20.09*	9.77	0.29*	0.16	5.13	3.60	474.29	260.19
15	PGRU 99-028	2.84*	2.76*	43.36*	37.75*	21.95*	19.84*	0.27*	0.26*	5.36*	4.12*	1316.69*	1280.00*
16	VH 85-5	1.84	1.49	41.11*	29.12	15.03	7.14	0.23	0.14	4.68	3.17	874.12	600.19
17	UK 2289	2.41*	1.66*	38.45	31.95	17.55*	10.09	0.21	0.17	4.40	2.20	1136.20*	890.60*
18	PLU 10-4	1.94	1.78*	40.17	35.87*	15.63	9.82	0.24	0.13	4.74	2.81	899.13*	590.16
19	LBG 783	1.89	1.49	40.33	35.82*	13.88	6.95	0.20	0.11	4.29	2.72	843.12	510.00
20	KU 15-15	1.97	1.76*	39.63	32.19	11.77	7.02	0.24	0.17	4.77	2.67	862.47	375.25
21	LBG 709	2.48*	2.00*	41.46*	35.72*	15.72	9.61	0.22	0.12	4.43	2.49	1120.90*	890.40*
22	KU 15-9	2.99*	2.92*	43.46*	42.76*	27.65*	25.89*	0.27*	0.25*	5.89*	5.50*	1719.75*	1685.45*
23	KU 708	1.90	1.64*	38.70	32.41	13.86	6.10	0.24	0.14	4.64	3.16	973.19*	480.00
24	KU 15-2	1.94	1.70*	33.92	27.12	19.00*	9.94	0.33*	0.19	5.43*	3.00	811.72	600.00

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25	LBG 20	2.00	1.72*	34.71	21.57	19.96*	8.17	0.32*	0.16	5.29*	2.99	905.53*	675.14*
26	KU 15-10	1.68	1.41	31.93	28.17	13.82	7.09	0.26*	0.14	4.69	2.14	817.27	320.25
27	LBG 752	1.89	1.47	34.55	25.27	14.36	9.72	0.24	0.11	4.45	2.20	991.89*	691.90*
28	LBG 708	1.67	1.31	30.27	22.19	16.34	7.89	0.25	0.16	4.44	3.10	634.31	410.00
29	KU 15-7	1.89	1.59	34.55	23.25	15.14	6.14	0.25	0.20	4.45	2.98	1138.30*	890.00*
30	LBG 645	1.12	0.89	23.66	27.24	16.40	8.27	0.30*	0.24*	4.91	3.14	513.55	285.00
31	KU 15-20	1.94	1.67*	32.44	30.12	9.60	6.21	0.17	0.11	3.62	2.71	1018.27*	665.90
32	CN 8072	1.45	1.10	32.33	29.17	14.81	9.00	0.21	0.14	4.10	2.19	762.59	480.10
33	P 726	1.62	1.17	32.33	25.12	15.41	6.79	0.28*	0.17	4.72	2.24	791.57	600.00
34	IPU 10-4	1.40	1.01	36.47	30.12	19.73*	8.36	0.27*	0.22	4.84	2.89	801.20	585.10
35	RUG 44	1.34	1.11	30.98	26.00	15.57	7.81	0.24	0.15	4.59	2.61	605.41	325.20
36	CPS 35	1.44	0.98	30.84	26.92	9.53	4.10	0.14	0.09	3.55	2.00	512.25	299.00
37	LBG 788	1.49	1.12	30.29	24.20	10.02	4.27	0.14	0.10	3.39	2.64	544.63	278.14
38	KU 15-13	1.72	1.20	33.69	22.97	12.89	7.11	0.18	0.12	4.17	2.86	859.07	660.95
39	KU – 323	1.97	1.47	30.46	23.00	10.35	6.21	0.14	0.08	3.67	2.18	1005.65*	700.80*
40	P 728	1.11	0.96*	33.48	29.82	5.02	2.80	0.09	0.03	2.64	1.99	400.64	280.20
41	KU 15-11	1.47	1.19	29.03	21.15	9.51	4.16	0.14	0.09	3.81	2.15	664.90	440.16
42	LBG 685	1.09	0.94	32.58	20.20	5.88	2.76	0.08	0.04	2.65	1.10	386.88	200.40
43	UTTARA	2.10*	1.48	31.54	24.21	9.59	4.24	0.15	0.10	3.99	2.75	1099.21*	676.69*
44	KU 15-4	1.65	1.29	33.36	27.75	7.27	2.99	0.10	0.07	3.26	2.16	722.77	588.25
45	PU 31	1.46	1.17	31.11	29.12	6.19	3.04	0.16	0.10	4.10	2.88	554.66	280.40
46	LBG 623	2.20*	1.64*	38.45	31.95	7.41	3.07	0.17	0.10	4.68	2.47	1087.07*	680.00*
47	LBG 787	1.58	1.21	40.17	25.87	12.70	5.99	0.15	0.08	4.04	2.10	666.19	418.00
48	LBG 791	1.24	0.94	40.33	25.82	10.19	4.81	0.16	0.09	4.11	2.36	495.34	281.16
49	KU 15-16	2.19*	1.40	36.63	32.19	11.27	6.16	0.17	0.08	4.27	2.18	1129.80*	840.30*
50	LBG 722	1.48	1.07	36.46	30.72	10.54	2.34	0.18	0.11	4.34	2.27	543.17	290.15
Grand Mean		1.82	1.44	35.94	29.50	13.34	7.41	0.20	0.13	4.18	2.57	839.84	596.00
SEM		0.185	0.199	3.25	2.18	3.56	4.16	0.06	0.10	1.10	1.05	57.45	72.10
CV%		5.32	6.11	0.92	0.14	0.9	0.800	2.74	1.89	3.56	3.61	120.62	95.44

Table 2. Percent infection per plant and Disease scoring scale of studied blackgram genotypes

S.No	Genotype	Percent infection	Disease scoring scale* (1-9 scale)	S.No	Genotype	Percent infection	Disease scoring scale* (1-9 scale)
1	PU 30	50.19	4	26	KU 15-10	21.80	2
2	KU 15-19	61.18	6	27	LBG 752	34.54	4
3	KU 15-6	10.57	1	28	LBG 708	64.39	6
4	P 1070	76.72	7	29	KU 15-7	20.61	2
5	LBG 777	77.77	7	30	LBG 645	79.02	8
6	LBG 775	43.52	4	31	KU 15-20	35.38	4
7	P 205	34.91	3	32	CN 8072	65.39	6
8	SPS 26	73.44	7	33	P 726	34.17	4
9	KU 15-3	31.81	4	34	IPU 10-4	51.58	5
10	GKU 02-1	30.38	3	35	RUG 44	73.51	7
11	KU 15-14	35.70	3	36	CPS 35	77.89	8
12	T 9	80.00	8	37	LBG 788	81.89	8
13	TU 18	10.29	1	38	KU 15-13	36.37	4
14	TBG 104	78.75	8	39	KU – 323	38.00	3
15	PGRU 99-028	10.81	1	40	P 728	74.54	8
16	VH 85-5	32.52	4	41	KU 15-11	62.00	6
17	UK 2289	17.94	2	42	LBG 685	74.00	8
18	PLU 10-4	59.46	5	43	UTTARA	42.12	4
19	LBG 783	55.84	5	44	KU 15-4	52.50	5

ISSN: 2349-7637 (Online)

20	KU 15-15	71.56	7	45	PU 31	79.00	8
21	LBG 709	22.57	2	46	LBG 623	32.75	4
22	KU 15-9	10.96	1	47	LBG 787	65.71	6
23	KU 708	62.89	6	48	LBG 791	73.33	8
24	KU 15-2	35.64	4	49	KU 15-16	27.60	2
25	LBG 20	45.05	4	50	LBG 722	95.12	9

Table 3. Grouping of blackgram genotypes screened against YMV basing on morphological, physiological, yield characters and 1-9 arbitrary scale

Rating	Reaction	Genotype
1.0 – 2.0	Resistant (R)	KU 15-6, TU 18, PGRU 99-028 and KU 15-9, UK 2289, LBG 709, KU 15-7, KU 15-16
2.1 – 4.0	Moderately Resistant (MR)	P 205, GKU 02-1, KU 15-14, KU 323, PU 30, LBG 775, KU 15-3, VH 85-5, KU 15-2, LBG 20, LBG 752, KU 15-20, P 726, KU 15-13, UTTARA, LBG 623
4.1 – 5.0	Moderately Susceptible (SC)	PLU 10-4, LBG 783, IPU 10-4, KU 15-4
5.1 – 7.0	Susceptible (S)	KU 15-19, KU 708, LBG 708, CN 8072, KU 15-11 and LBG 787, P 1070, LBG 777, SPS 26, KU 15-15, KU 15-10, RUG 44
7.1 – 9.0	Highly Susceptible (HS)	T9, TBG 104, LBG 645, CPS 35, LBG 788, P 728, LBG 685, PU 31, LBG 791, LBG 722

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