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Growth and Dry Matter Partitioning Efficiency of Blackgram Genotypes Influenced by Leaf Curl Disease under Natural Field Conditions

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A B S T R A C T

A field experiment was conducted to evaluate the performance of twenty five blackgram genotypes under naturally epidemic conditions to leaf curl disease. The experiment was under taken during the late *rabi* 2018-19 and 2019-20 in a randomized block design replicated thrice. The investigation has focused on the study of variation in the dry matter production efficiency of the genotypes as influenced by leaf curl disease infection. The results obtained indicated that the leaf curl disease has severely affected the growth and dry matter partitioning efficiency of all the blackgram genotypes tested. The genotypes that show resistance to leaf curl disease showed less reduction dry weights. Leaf dry weight, pod dry weight and total dry matter showed a highly significant negative correlation with leaf curl disease at 60 DAS and maturity. The resistant genotype TU 40 showed higher partitioning efficiency and pod dry weights.

Introduction

India is the largest producer and consumer of pulses in the world (Chauhan *et al.*, 2016). Blackgram is one of the most important pulse crop grown in India. It is also the third most cultivated pulse crop in terms of area after pigeonpea and chickpea with a production of 35.6 lakh tones during 2017-18 (ASG, 2018). Blackgram is also a nutritionally important crop with a good amount of dietary protein content.

India is contributing 70% of the world's blackgram production yet India imports huge quantities majorly from Myanmar. This can be attributed to the lower genetic yield potential of blackgram, lesser partitioning efficiency and lower concern given to the crop grown on marginal lands with higher

biotic and abiotic stresses. The major biotic stress factors that influence the crop growth of blackgram are a class of viral diseases which include mungbean yellow mosaic virus (MYMV), leaf curl virus disease caused by groundnut bud necrosis virus (GBNV) and urdbean leaf crinkle virus (ULCV) (Biswas *et al.,* 2009).

It is clear from various reports that virus infection reduced the plant growth and dry biomass and fresh weights of tomato plants infected with yellow mosaic or aucuba. The virus infected plants showed reduced carbohydrate and residual dry matter contents in their stems (Caldwell, 1934). In the present study the genotype screening was carried out based on the retention of their partitioning efficiency among the blackgram genotypes.

Materials and Methods

A field experiment was conducted involving twenty five blackgram genotypes LBG 623, LBG 752, LBG 787, LBG 806, LBG 808, LBG 818, LBG 822, LBG 828, LBG 881, LBG 884, LBG 888, LBG 951, GKB 1, GKB 2, GKB 3, GKB 4, GBG 1, VBG 13-3, VBG 14-16, TBG 125, TBG 129, TBG 104, PBG 32-2, PU 31 and TU 40in three replications at RARS, Lam. The samples that are brought for destructive sampling were oven-dried at 80° for 48 hours and the dry weights of the leaves, stem, roots and pods were recorded and expressed as g plant-1. The total dry matter was calculated by adding leaves, stem, root and pod dry weights and expressed as g plant^{-1}.

Results and Discussion

Dry matter partitioning

Virus infection reduces plant growth by reducing dry matter accumulation. Dry matter partitioning is one of the important measures to observe the damage caused by thrips and viruses transmitted by them. The dry weights of leaf, stem, root and pod were recorded in the genotypes and were discussed hereunder.

Leaf dry weight (g plant^{-1})

GBNV infection severely reduces the leaf dry weights by more than half in infected plants because the bud necrosis reduces the leaf number and size. After 30 DAS GBNV infection causes only leaf curling reducing the leaf dry weight up to 30%. The leaf dry weights showed significant variation among the genotypes at 20, 40, 60 DAS and at maturity during both the seasons (Table 1).

Higher leaf dry weights were recorded in the genotypes TU 40 (5.274 g plant^{-1}) followed by LBG 884 (5.052 g plant^{-1}) and LBG 888 (4.725 g plant^{-1}) at maturity which are grouped under resistant category. Lower leaf dry weights at maturity were recorded in the genotypes GKB 4 (2.512 g plant^{-1}) under the moderately resistant category preceded by TBG 104 (2.763 g plant^{-1}) under susceptible category.

Mean leaf dry weights of resistant genotypes are 0.166, 1.501, 4.096 and 4.124 g plant^{-1} at 20, 40, 60 DAS and maturity respectively. The mean leaf dry weights of moderately resistant genotypes are 0.126, 1.853, 3.525 and 3.861 g plant^{-1} at 20, 40,60 DAS and maturity respectively. The mean dry weights of moderately susceptible genotypes are 0.175, 1.346, 3.278 and 3.324 g plant^{-1}at 20, 40,60 DAS and maturity respectively. The mean leaf dry weights of susceptible genotypes are 0.159, 1.395, 3.430 and 3.471 g plant^{-1} at 20, 40,60 DAS and maturity respectively.

Correlation studies between leaf dry weight and leaf curl disease incidence indicated that a highly significant negative correlation was

noticed at 60 DAS (r = -0.536) and maturity (r = -0.541) and a non-significant correlation was observed at 20 DAS and 40 DAS. Correlation of leaf dry weight with thrips population was observed to be negative and significant at 60 DAS (r = -0.457) and maturity (r = -0.467) and non-significant at 20 DAS and 40 DAS (Table 1).

Results obtained indicated that the leaf dry weight of susceptible genotypes was highly affected by leaf curl disease incidence and thrips population. The leaf dry weight susceptible genotypes were decreased more due to the leaf curl effect at 60 DAS and maturity. The leaf dry weight of cowpea showed a decrease due to the infection complex caused by CMV and BICMV (Pio-Ribeiro *et al.,* 1978).

Stem dry weight (g plant^{-1})

Leaf curl disease in blackgram is caused by GBNV and its infection at initial stages of crop growth causes bud necrosis disease that reduces the stem dry weights phenomenally and leads to partial or complete yield loss. Stem dry weight showed a significant variation among the genotypes at 20, 40, 60 DAS and maturity during both the seasons (Table 2). Mean values of stem dry weights of resistant genotypes are 0.091, 1.273, 3.774 g and 3.759 g plant^{-1} at 20, 40, 60 DAS and at maturity respectively. The mean stem dry weights of moderately resistant genotypes are 0.076, 1.010, 2.228 and 2.450 g plant^{-1} at 20, 40, 60 DAS and at maturity respectively.

The mean stem dry weights of moderately susceptible genotypes are 0.086, 1.080, 2.658 and 2.804 g plant^{-1} at 20, 40, 60 DAS and at maturity respectively. The mean stem dry weights of susceptible genotypes are 0.075, 1.112, 2.937and 2.790 g plant^{-1} at 20, 40,60 DAS and at maturity respectively.

Higher stem dry weights were recorded in the genotypes TU 40 (5.032 g plant^{-1}) followed by TBG 129 (4.331 g plant^{-1}) and LBG 884 (4.045 g plant^{-1}) at maturity which are grouped under resistant category. Lower stem dry weights at maturity were recorded in the genotypes LBG 881 (2.075 g plant^{-1}) preceded by LBG 623 (2.216 g plant^{-1}) under the moderately resistant category.

Correlation studies of stem dry weight with leaf curl disease incidence and thrips population showed a highly significant negative correlation with both leaf curl disease incidence (%) and thrips population at 60 DAS (r = -0.484 and -0.530) and maturity (r = -0.549 and -0.617) respectively. The stem dry weight with leaf curl disease incidence (%) and thrips population showed a non-significant negative correlation at 20 DAS and 40 DAS (Table 6).

The stem dry weights of resistant genotypes were higher when compared to any other category indicating that the resistant genotypes possess higher stem dry weights. These results indicated that the resistant genotypes were less affected by thrips and leaf curl disease. Latham *et al.,* (2004) observed the loss of stem dry weight in lentil susceptible genotypes due to the alfalfa mosaic virus (AMV) infection. The virus infected plants showed reduced residual dry matter contents in their stems of tomato plants infected with aucuba or yellow mosaic virus (Caldwell, 1934).

Root dry weight (g plant^{-1}):

Root dry weight values varied significantly among the blackgram genotypes at 20, 40, 60 DAS and maturity during both the seasons (Table 3). Mean values of root dry weights of resistant genotypes are 0.064, 0.534, 1.346 and 1.280 g plant^{-1} at 20, 40, 60 DAS and at maturity respectively. Mean root dry weights

of moderately resistant genotypes are 0.053, 0.469, 0.981 and 0.912 g plant^{-1} at 20, 40, 60 DAS and at maturity respectively.

The mean root dry weights of moderately susceptible genotypes are 0.063, 0.490, 1.157 and 1.083 g plant^{-1} at 20, 40, 60 DAS and at maturity respectively. The mean root dry weights of susceptible genotypes are 0.060, 0.497, 1.150 and 1.081 g plant^{-1} at 20, 40, 60 DAS and at maturity respectively.

Higher root dry weights were recorded in the genotypes TU 40 (1.485 g plant^{-1}) followed by LBG 884 (1.474 g plant^{-1}) and VBG 13-3 (1.411 g plant^{-1}) at maturity which are grouped under resistant category. Lower root dry weights at maturity were recorded in the genotypes GKB 1 (0.705 g plant^{-1}) under moderately resistant category preceded by GKB 3 (0.803 g plant^{-1}) under the resistant category.

Root dry weight not only depends on the viral infection but also the plant stature and genotypic character. It is observed that resistant genotypes have higher root dry weights. These results are in corroboration with the findings of Terry and Hahn, (1980) in cassava genotypes and Hema *et al.*, (2015) in soybean genotypes.

Pod dry weight (g plant^{-1})

Pod dry weight values showed a significant variation among the blackgram genotypes during both the seasons late *rabi* 2018-19 and late *rabi* 2019-20 at 60 DAS and maturity (Table 4).

Mean pod dry weights values of resistant genotypes are 2.159 and 3.289 g plant-1 at 60 DAS and maturity respectively. The mean pod dry weights of moderately resistant genotypes are 1.943 and 2.698 g plant^{-1} at 60 DAS and maturity respectively. The mean pod dry weights of moderately susceptible genotypes are 1.635 and 2.725 g plant^{-1} at 60 DAS and maturity respectively. Mean pod dry weights of susceptible genotypes are 1.703 and 2.803 g plant^{-1} at 60 DAS and maturity respectively

Higher pod dry weights were recorded in the genotypes TU 40 (3.696 g plant^{-1}) followed by LBG 884 (3.538 g plant^{-1}) and LBG 888 (3.462 g plant^{-1}) at maturity which are grouped under resistant category. Lower pod dry weights at maturity were recorded in the genotypes LBG 951 (2.479 g plant^{-1}) preceded by LBG 787 (2.599 g plant^{-1}) under the moderately susceptible category.

Correlation studies indicated that pod dry weight and leaf curl disease incidence showed a highly significant negative correlation at 60 DAS (r = -0.636) and maturity (r = -0.576) and a similar highly significant negative correlation was obtained with thrips population at 60 DAS (r = -0.724) and maturity (r = -0.670) (Table 6). Pod dry weight is a direct measurement parameter for yield per plant which is purely dependent on the genetic yield potential of a genotype the virus-resistant genotypes has less reduction in pod dry weight compared with the susceptible ones. These results are in acceptance with the findings of Latham *et al.*, 2004 in CMV infected cowpea genotypes.

Total dry matter (TDM) (g plant^{-1})

Total dry matter of a plant indicates the growth in terms of dry mass accumulated and it is very important to measure TDM in the viral diseases like leaf curl disease because its infection significantly reduces TDM in susceptible genotypes. A significant variation was observed among the genotypes for TDM at all the measured and TDM increased in all the genotypes from 20 DAS to maturity during both the seasons (Table 5).

Table.1 Variability in leaf dry weight (g plant^{-1}) of blackgram genotypes as influenced by leaf curl disease incidence

S. No.	Genotypes	20 DAS			40 DAS			60 DAS			At Maturity		
		Late *rabi* 2018-19	Late *rabi* 2019-20	Pooled mean	Late *rabi* 2018-19	Late *rabi* 2019-20	Pooled mean	Late *rabi* 2018-19	Late *rabi* 2019-20	Pooled mean	Late *rabi* 2018-19	Late *rabi* 2019-20	Pooled mean
	Resistant												
1	**LBG 884**	0.233	0.216	0.225	1.588	1.496	1.542	5.340	4.972	5.156	5.293	4.811	5.052
2	**LBG 888**	0.199	0.178	0.188	1.580	1.398	1.489	4.942	4.462	4.702	4.948	4.503	4.725
3	**GBG 1**	0.169	0.148	0.159	1.294	1.128	1.211	3.585	3.257	3.421	3.694	3.237	3.465
4	**VBG 13-3**	0.142	0.113	0.128	1.341	1.226	1.284	3.940	3.700	3.820	4.010	3.788	3.899
5	**TBG 129**	0.141	0.108	0.125	1.827	1.723	1.775	3.850	3.425	3.637	3.948	3.360	3.654
6	**PBG 32-2**	0.193	0.186	0.190	1.421	1.319	1.370	3.629	3.531	3.580	3.583	3.609	3.596
7	**TU 40**	0.196	0.191	0.194	2.038	1.905	1.972	5.328	5.044	5.186	5.436	5.113	5.274
8	**GKB 3**	0.133	0.115	0.124	1.400	1.331	1.366	3.404	3.128	3.266	3.474	3.173	3.323
	Mean	0.176	0.157	0.166	1.561	1.441	1.501	4.252	3.940	4.096	4.298	3.949	4.124
	Moderately resistant												
9	**LBG 623**	0.151	0.138	0.145	1.887	1.681	1.784	3.528	3.267	3.398	3.582	3.210	3.396
10	**LBG 806**	0.143	0.129	0.136	1.288	1.185	1.237	3.102	2.662	2.882	3.163	2.808	2.986
11	**LBG 808**	0.178	0.161	0.170	1.344	1.199	1.271	3.079	2.818	2.948	3.164	2.841	3.003
12	**LBG 818**	0.168	0.163	0.165	1.693	1.570	1.631	3.641	2.857	3.249	3.691	2.904	3.297
13	**LBG 881**	0.152	0.141	0.147	1.250	1.084	1.167	2.745	2.502	2.624	2.797	2.506	2.651
14	**GKB 1**	0.175	0.150	0.162	1.284	1.188	1.236	3.055	2.751	2.903	3.034	2.854	2.944
15	**GKB 2**	0.143	0.142	0.143	1.248	1.250	1.249	3.137	2.829	2.983	3.370	2.718	3.044
16	**GKB 4**	0.161	0.144	0.153	1.082	0.893	0.988	2.709	2.277	2.493	2.770	2.254	2.512
17	**VBG 14-16**	0.136	0.115	0.126	1.885	1.821	1.853	3.905	3.525	3.715	4.056	3.666	3.861
	Mean	0.151	0.138	0.145	1.887	1.681	1.784	3.528	3.267	3.398	3.582	3.210	3.396
	Moderately susceptible												
18	**LBG 752**	0.252	0.231	0.241	1.785	1.654	1.720	3.723	3.474	3.598	3.722	3.557	3.640
19	**LBG 787**	0.169	0.150	0.160	1.642	1.456	1.549	3.658	3.267	3.462	3.669	3.383	3.526
20	**LBG 822**	0.138	0.127	0.133	1.307	1.138	1.222	3.590	3.193	3.392	3.576	3.168	3.372
21	**LBG 828**	0.182	0.155	0.169	1.098	1.049	1.074	3.266	2.905	3.086	3.244	3.016	3.130
22	**LBG 951**	0.178	0.151	0.164	1.273	1.164	1.219	2.936	2.699	2.817	3.055	2.772	2.913
23	**PU 31**	0.188	0.178	0.183	1.370	1.221	1.296	3.446	3.179	3.313	3.489	3.233	3.361
	Mean	0.185	0.165	0.175	1.413	1.280	1.346	3.436	3.119	3.278	3.459	3.188	3.324
	Susceptible												
24	**TBG 125**	0.138	0.129	0.133	1.296	1.196	1.246	3.510	3.240	3.375	3.736	3.032	3.384
25	**TBG 104**	0.133	0.107	0.120	1.170	1.096	1.133	2.979	2.501	2.740	2.969	2.557	2.763
	Mean	0.136	0.118	0.127	1.233	1.146	1.190	3.245	2.871	3.058	3.352	2.794	3.073
Grand mean		0.168	0.151	0.159	1.456	1.335	1.395	3.601	3.259	3.430	3.659	3.283	3.471
SE(m)±		0.01	0.00	0.00	0.03	0.04	0.03	0.05	0.05	0.04	0.08	0.08	0.06
CD(0.05)		0.02	0.01	0.01	0.09	0.11	0.08	0.15	0.13	0.11	0.22	0.22	0.17
CV(%)		7.87	3.64	5.00	3.68	4.80	3.33	2.58	2.47	1.90	3.70	3.99	3.01

Table.2 Variability in stem dry weight (g plant^{-1}) of Blackgram genotypes as influenced by leaf curl disease incidence

S. No.	Genotypes	20 DAS			40 DAS			60 DAS			At Maturity		
		Late *rabi* 2018-19	Late *rabi* 2019-20	Pooled mean	Late *rabi* 2018-19	Late *rabi* 2019-20	Pooled mean	Late *rabi* 2018-19	Late *rabi* 2019-20	Pooled mean	Late *rabi* 2018-19	Late *rabi* 2019-20	Pooled mean
	Resistant												
1	**LBG 884**	0.105	0.084	0.095	1.537	1.428	1.483	4.170	3.751	3.961	4.261	3.828	4.045
2	**LBG 888**	0.123	0.099	0.111	1.136	1.028	1.082	3.496	3.293	3.394	3.406	3.259	3.332
3	**GBG 1**	0.100	0.083	0.092	0.951	0.918	0.935	2.587	2.665	2.626	3.160	3.188	3.174
4	**VBG 13-3**	0.106	0.079	0.092	1.179	1.062	1.120	3.447	3.258	3.353	3.596	3.446	3.521
5	**TBG 129**	0.089	0.077	0.083	1.427	1.339	1.383	4.580	4.288	4.434	4.523	4.138	4.331
6	**PBG 32-2**	0.097	0.073	0.085	1.315	1.202	1.259	4.288	4.174	4.231	3.799	3.908	3.854
7	**TU 40**	0.091	0.085	0.088	1.688	1.579	1.634	5.250	5.060	5.155	5.135	4.928	5.032
8	**GKB 3**	0.090	0.078	0.084	1.344	1.223	1.284	3.220	2.859	3.040	2.936	2.634	2.785
	Mean	0.100	0.082	0.091	1.322	1.222	1.273	3.880	3.669	3.774	3.852	3.666	3.759
	Moderately resistant												
9	**LBG 623**	0.105	0.096	0.101	1.120	1.027	1.074	2.118	2.060	2.089	2.284	2.148	2.216
10	**LBG 806**	0.073	0.062	0.068	0.923	0.813	0.868	2.262	1.863	2.062	2.471	2.205	2.338
11	**LBG 808**	0.090	0.063	0.077	0.986	0.848	0.917	2.328	2.084	2.206	2.721	2.507	2.614
12	**LBG 818**	0.090	0.076	0.083	1.399	1.304	1.352	3.058	2.429	2.743	3.321	2.793	3.057
13	**LBG 881**	0.079	0.058	0.068	0.894	0.803	0.848	1.992	1.897	1.944	2.125	2.024	2.075
14	**GKB 1**	0.070	0.062	0.066	0.922	0.824	0.873	2.128	1.896	2.012	2.457	2.335	2.396
15	**GKB 2**	0.081	0.065	0.073	0.992	0.863	0.927	2.447	1.958	2.203	2.364	2.076	2.220
16	**GKB 4**	0.073	0.065	0.069	0.821	0.697	0.759	1.989	1.752	1.871	2.507	2.193	2.350
17	**VBG 14-16**	0.089	0.064	0.077	1.528	1.413	1.471	3.127	2.722	2.924	2.957	2.612	2.785
	Mean	0.083	0.068	0.076	1.065	0.955	1.010	2.383	2.073	2.228	2.579	2.321	2.450
	Moderately susceptible												
18	**LBG 752**	0.109	0.108	0.109	1.405	1.306	1.356	2.893	2.753	2.823	3.005	2.952	2.979
19	**LBG 787**	0.088	0.080	0.084	1.112	1.009	1.060	2.460	2.273	2.366	2.585	2.455	2.520
20	**LBG 822**	0.078	0.061	0.070	1.149	1.038	1.094	3.124	2.950	3.037	2.955	2.792	2.874
21	**LBG 828**	0.093	0.064	0.079	0.933	0.820	0.876	2.843	2.402	2.622	2.944	2.747	2.845
22	**LBG 951**	0.093	0.086	0.089	1.045	0.955	1.000	2.415	2.244	2.329	2.806	2.631	2.719
23	**PU 31**	0.094	0.074	0.084	1.160	1.025	1.093	2.871	2.672	2.772	2.995	2.781	2.888
	Mean	0.093	0.079	0.086	1.134	1.026	1.080	2.768	2.549	2.658	2.882	2.726	2.804
	Susceptible												
24	**TBG 125**	0.070	0.073	0.072	1.070	0.994	1.032	2.690	2.559	2.624	2.970	2.424	2.697
25	**TBG 104**	0.082	0.074	0.078	1.087	0.943	1.015	3.465	3.034	3.250	3.099	2.668	2.883
	Mean	0.076	0.074	0.075	1.079	0.969	1.024	3.078	2.797	2.937	3.035	2.546	2.790
	Grand mean	0.090	0.076	0.083	1.165	1.058	1.112	3.010	2.756	2.883	3.095	2.867	2.981
	SE(m)±	0.006	0.005	0.004	0.048	0.034	0.032	0.035	0.038	0.027	0.064	0.060	0.048
	CD(0.05)	0.016	0.014	0.012	0.137	0.098	0.092	0.101	0.107	0.077	0.182	0.172	0.137
	CV(%)	10.97	10.98	8.61	7.14	5.64	5.02	2.04	2.38	1.64	3.57	3.65	2.80

Table.3 Variability in root dry weight (g plant^{-1}) of blackgram genotypes as influenced by leaf curl disease incidence

S. No.	Genotypes	20 DAS			40 DAS			60 DAS			At Maturity		
		Late *rabi* 2018-19	Late *rabi* 2019-20	Pooled mean	Late *rabi* 2018-19	Late *rabi* 2019-20	Pooled mean	Late *rabi* 2018-19	Late *rabi* 2019-20	Pooled mean	Late *rabi* 2018-19	Late *rabi* 2019-20	Pooled mean
	Resistant												
1	**LBG 884**	0.065	0.061	0.063	0.617	0.508	0.562	1.660	1.421	1.541	1.604	1.343	1.474
2	**LBG 888**	0.061	0.056	0.058	0.574	0.473	0.523	1.386	1.218	1.302	1.348	1.140	1.244
3	**GBG 1**	0.051	0.047	0.049	0.478	0.377	0.427	1.157	1.061	1.109	1.093	0.987	1.040
4	**VBG 13-3**	0.078	0.070	0.074	0.559	0.453	0.506	1.562	1.390	1.476	1.496	1.327	1.411
5	**TBG 129**	0.056	0.047	0.052	0.636	0.499	0.567	1.549	1.402	1.476	1.473	1.318	1.395
6	**PBG 32-2**	0.082	0.075	0.079	0.602	0.511	0.557	1.525	1.392	1.458	1.458	1.315	1.387
7	**TU 40**	0.072	0.061	0.067	0.759	0.673	0.716	1.613	1.471	1.542	1.582	1.388	1.485
8	**GKB 3**	0.072	0.067	0.069	0.485	0.347	0.416	0.976	0.751	0.864	0.932	0.675	0.803
	Mean	0.067	0.061	0.064	0.589	0.480	0.534	1.429	1.263	1.346	1.373	1.187	1.280
	Moderately resistant												
9	**LBG 623**	0.069	0.060	0.064	0.613	0.511	0.562	1.028	0.878	0.953	0.968	0.803	0.885
10	**LBG 806**	0.059	0.049	0.054	0.494	0.378	0.436	1.115	0.956	1.035	1.060	0.889	0.975
11	**LBG 808**	0.062	0.052	0.057	0.427	0.321	0.374	0.978	0.792	0.885	0.888	0.734	0.811
12	**LBG 818**	0.046	0.037	0.042	0.617	0.528	0.573	1.104	0.910	1.007	1.033	0.836	0.934
13	**LBG 881**	0.036	0.034	0.035	0.538	0.418	0.478	1.148	1.079	1.113	1.070	1.005	1.038
14	**GKB 1**	0.054	0.051	0.053	0.414	0.310	0.362	0.855	0.695	0.775	0.786	0.624	0.705
15	**GKB 2**	0.056	0.052	0.054	0.469	0.379	0.424	1.033	0.847	0.940	0.983	0.779	0.881
16	**GKB 4**	0.063	0.056	0.060	0.450	0.358	0.404	1.002	0.989	0.995	0.934	0.906	0.920
17	**VBG 14-16**	0.062	0.052	0.057	0.651	0.563	0.607	1.236	1.015	1.125	1.186	0.935	1.061
	Mean	0.056	0.049	0.053	0.519	0.418	0.469	1.055	0.907	0.981	0.990	0.835	0.912
18	**LBG 752**	0.080	0.071	0.076	0.684	0.542	0.613	1.400	1.201	1.300	1.330	1.126	1.228
19	**LBG 787**	0.078	0.068	0.073	0.584	0.393	0.489	1.176	1.026	1.101	1.110	0.957	1.033
20	**LBG 822**	0.051	0.042	0.047	0.561	0.398	0.480	1.449	1.243	1.346	1.391	1.158	1.275
21	**LBG 828**	0.079	0.071	0.075	0.450	0.331	0.390	1.051	0.890	0.971	0.971	0.816	0.893
22	**LBG 951**	0.057	0.050	0.054	0.511	0.355	0.433	1.160	0.935	1.047	1.081	0.860	0.971
23	**PU 31**	0.087	0.078	0.083	0.589	0.480	0.534	1.244	1.105	1.175	1.167	1.025	1.096
	Mean	0.072	0.063	0.068	0.563	0.417	0.490	1.247	1.067	1.157	1.175	0.990	1.083
24	**TBG 125**	0.055	0.048	0.052	0.590	0.445	0.517	1.347	1.146	1.247	1.294	1.077	1.186
25	**TBG 104**	0.065	0.055	0.060	0.533	0.419	0.476	1.049	0.897	0.973	0.986	0.818	0.902
	Mean	0.060	0.052	0.056	0.562	0.432	0.497	1.198	1.022	1.110	1.140	0.948	1.044
Grand mean		0.064	0.056	0.060	0.555	0.439	0.497	1.232	1.068	1.150	1.169	0.994	1.081
SE(m)±		0.004	0.003	0.003	0.019	0.021	0.016	0.056	0.067	0.050	0.042	0.069	0.044
CD(0.05)		0.012	0.009	0.009	0.053	0.059	0.046	0.158	0.192	0.142	0.120	0.197	0.125
CV(%)		11.63	9.62	9.61	5.84	8.24	5.62	7.83	10.93	7.51	6.27	12.11	7.05

Table.4 Variability in pod dry weight (g plant^{-1}) of blackgram genotypes as influenced by leaf curl disease incidence

S. No.	Genotypes	60 DAS			At Maturity		
		Late *rabi* 2018-19	Late *rabi* 2019-20	Pooled mean	Late *rabi* 2018-19	Late *rabi* 2019-20	Pooled mean
	Resistant						
1	**LBG 884**	1.882	1.712	1.797	3.685	3.391	3.538
2	**LBG 888**	2.101	1.897	1.999	3.647	3.277	3.462
3	**GBG 1**	2.267	2.004	2.135	3.088	2.811	2.950
4	**VBG 13-3**	2.334	2.006	2.170	3.254	2.993	3.123
5	**TBG 129**	2.435	2.214	2.324	3.541	3.278	3.410
6	**PBG 32-2**	2.438	2.208	2.323	3.361	3.097	3.229
7	**TU 40**	2.647	2.399	2.523	3.825	3.566	3.696
8	**GKB 3**	2.110	1.898	2.004	3.025	2.786	2.906
	Mean	2.277	2.042	2.159	3.428	3.150	3.289
Moderately resistant							
9	**LBG 623**	1.311	1.075	1.193	2.839	2.559	2.699
10	**LBG 806**	1.899	1.610	1.754	3.293	2.884	3.089
11	**LBG 808**	1.883	1.606	1.745	3.304	3.066	3.185
12	**LBG 818**	1.612	1.427	1.519	2.839	2.601	2.720
13	**LBG 881**	2.167	1.951	2.059	3.428	3.215	3.321
14	**GKB 1**	2.003	1.730	1.866	3.058	2.795	2.926
15	**GKB 2**	1.954	1.725	1.839	2.601	2.444	2.522
16	**GKB 4**	1.787	1.440	1.614	2.803	2.549	2.676
17	**VBG 14-16**	2.105	1.780	1.943	2.811	2.546	2.678
Moderately susceptible							
	Mean	1.858	1.594	1.726	2.997	2.740	2.868
18	**LBG 752**	1.860	1.678	1.769	2.933	2.673	2.803
19	**LBG 787**	1.825	1.534	1.679	2.730	2.468	2.599
20	**LBG 822**	1.584	1.329	1.457	2.839	2.572	2.706
21	**LBG 828**	1.586	1.373	1.479	3.223	2.980	3.101
22	**LBG 951**	1.895	1.464	1.680	2.610	2.349	2.479
23	**PU 31**	1.911	1.585	1.748	2.787	2.541	2.664
	Mean	1.777	1.494	1.635	2.854	2.597	2.725
	Susceptible						
24	**TBG 125**	1.799	1.521	1.660	2.868	2.823	2.845
25	**TBG 104**	1.996	1.495	1.745	2.896	2.627	2.761
	Mean	1.898	1.508	1.703	2.882	2.725	2.803
Grand Mean		1.976	1.706	1.841	3.091	2.836	2.964
SE(m)±		0.043	0.042	0.033	0.062	0.090	0.069
CD(0.05)		0.123	0.120	0.094	0.177	0.256	0.195
CV(%)		3.79	4.30	3.09	3.48	5.50	4.01

Table.5 Variability in total dry weight (g plant^{-1}) of Blackgram genotypes as influenced by leaf curl disease incidence

S. No.	Genotypes	20 DAS			40 DAS			60 DAS			At Maturity		
		Late *rabi* 2018-19	Late *rabi* 2019-20	Pooled mean	Late *rabi* 2018-19	Late *rabi* 2019-20	Pooled mean	Late *rabi* 2018-19	Late *rabi* 2019-20	Pooled mean	Late *rabi* 2018-19	Late *rabi* 2019-20	Pooled mean
	Resistant												
1	**LBG 884**	0.40	0.36	0.38	3.74	3.43	3.59	13.05	11.86	12.45	14.84	13.37	14.11
2	**LBG 888**	0.38	0.33	0.36	3.29	2.90	3.09	11.93	10.87	11.40	13.35	12.18	12.76
3	**GBG 1**	0.32	0.28	0.30	2.72	2.42	2.57	9.60	8.99	9.29	11.04	10.22	10.63
4	**VBG 13-3**	0.33	0.26	0.29	3.08	2.74	2.91	11.28	10.35	10.82	12.36	11.55	11.95
5	**TBG 129**	0.29	0.23	0.26	3.89	3.56	3.73	12.41	11.33	11.87	13.48	12.09	12.79
6	**PBG 32-2**	0.37	0.33	0.35	3.34	3.03	3.19	11.88	11.31	11.59	12.20	11.93	12.06
7	**TU 40**	0.36	0.34	0.35	4.49	4.16	4.32	14.84	13.97	14.41	15.98	15.00	15.49
8	**GKB 3**	0.29	0.26	0.28	3.23	2.90	3.07	9.71	8.64	9.17	10.37	9.27	9.82
	Mean	0.34	0.30	0.32	3.47	3.14	3.31	11.84	10.91	11.38	12.95	11.95	12.45
	Moderately resistant												
9	**LBG 623**	0.33	0.29	0.31	3.62	3.22	3.42	7.98	7.28	7.63	9.67	8.72	9.20
10	**LBG 806**	0.28	0.24	0.26	2.70	2.38	2.54	8.38	7.09	7.73	9.99	8.79	9.39
11	**LBG 808**	0.33	0.28	0.30	2.76	2.37	2.56	8.27	7.30	7.78	10.08	9.15	9.61
12	**LBG 818**	0.30	0.28	0.29	3.71	3.40	3.56	9.41	7.62	8.52	10.88	9.13	10.01
13	**LBG 881**	0.27	0.23	0.25	2.68	2.30	2.49	8.05	7.43	7.74	9.42	8.75	9.08
14	**GKB 1**	0.30	0.26	0.28	2.62	2.32	2.47	8.04	7.07	7.56	9.33	8.61	8.97
15	**GKB 2**	0.28	0.26	0.27	2.71	2.49	2.60	8.57	7.36	7.97	9.32	8.02	8.67
16	**GKB 4**	0.30	0.27	0.28	2.35	1.95	2.15	7.49	6.46	6.97	9.01	7.90	8.46
17	**VBG 14-16**	0.29	0.23	0.26	4.06	3.80	3.93	10.37	9.04	9.71	11.01	9.76	10.38
	Mean	0.30	0.26	0.28	3.02	2.69	2.86	8.51	7.41	7.96	9.86	8.76	9.31
	Moderately Susceptible												
18	**LBG 752**	0.44	0.41	0.43	3.87	3.50	3.69	9.88	9.11	9.49	10.99	10.31	10.65
19	**LBG 787**	0.34	0.30	0.32	3.34	2.86	3.10	9.12	8.10	8.61	10.09	9.26	9.68
20	**LBG 822**	0.27	0.23	0.25	3.02	2.57	2.80	9.75	8.72	9.23	10.76	9.69	10.23
21	**LBG 828**	0.35	0.29	0.32	2.48	2.20	2.34	8.75	7.57	8.16	10.38	9.56	9.97
22	**LBG 951**	0.33	0.29	0.31	2.83	2.47	2.65	8.41	7.34	7.87	9.55	8.61	9.08
23	**PU 31**	0.37	0.33	0.35	3.12	2.73	2.92	9.47	8.54	9.01	10.44	9.58	10.01
	Mean	0.35	0.31	0.33	3.11	2.72	2.92	9.23	8.23	8.73	10.37	9.50	9.94
	Susceptible												
24	**TBG 125**	0.26	0.25	0.26	2.96	2.64	2.80	9.35	8.47	8.91	10.87	9.36	10.11
25	**TBG 104**	0.28	0.24	0.26	2.79	2.46	2.62	9.49	7.93	8.71	9.95	8.67	9.31
	Mean	0.27	0.24	0.26	2.87	2.55	2.71	9.42	8.20	8.81	10.41	9.01	9.71
	SE(m)±	0.01	0.01	0.01	0.07	0.06	0.05	0.11	0.13	0.09	0.16	0.16	0.13
	CD(0.05)	0.03	0.02	0.02	0.19	0.17	0.14	0.31	0.37	0.27	0.45	0.45	0.36
	CV(%)	5.99	4.53	4.58	3.60	3.56	2.82	1.89	2.60	1.75	2.51	2.72	2.11

Table.6 Correlations of dry matter partitioning with leaf curl disease incidence and thrips population in blackgram

	Parameter	20 DAS	40 DAS	60 DAS	Maturity
Disease incidence	Leaf dry weight	-0.161^{NS}	-0.298^{NS}	-0.536**	-0.541**
Thrips population		-0.195^{NS}	-0.066^{NS}	-0.457*	-0.467*
Disease incidence	Stem dry weight	-0.277^{NS}	-0.358^{NS}	-0.484*	-0.549**
Thrips population		0.004^{NS}	-0.301^{NS}	-0.530**	-0.617**
Disease incidence	pod dry weight			-0.636**	-0.576**
Thrips population				-0.724**	-0.670**
Disease incidence	Total dry matter	-0.203^{NS}	-0.318^{NS}	-0.578**	-0.592**
Thrips population		-0.141^{NS}	-0.163^{NS}	-0.582**	-0.608**

** Indicates significant at 0.01 level of significance; * Indicates significant at 0.05 level of significance; ^{NS} Indicates non-significant

The mean TDM values of resistant genotypes are 0.32, 3.31, 11.38 and 12.45 g plant^{-1} at 20, 40, 60 DAS and at maturity respectively. The mean TDM values of moderately resistant genotypes are 0.28, 2.86, 7.96and 9.31 g plant^{-1} at 20, 40, 60 DAS and at maturity respectively.

The mean TDM values of moderately susceptible genotypes are 0.33, 2.92, 8.73 and 9.94 g plant^{-1} at 20, 40, 60 DAS and at maturity respectively. The mean TDM values of susceptible genotypes are 0.26, 2.71, 8.81 and 9.71 g plant^{-1} at 20, 40,60 DAS and maturity respectively.

Higher TDM values were recorded in the genotypes TU 40 (15.49 g plant^{-1}) followed by LBG 884 (14.11 g plant^{-1}) and TBG 129 (12.79 g plant^{-1}) at maturity which are grouped under resistant category. Lower TDM values at maturity were recorded in the genotypes LBG 951 and LBG 881 (9.08 g plant^{-1}) preceded by LBG 623 (9.20 g plant^{-1}) under the moderately resistant category.

Correlation studies revealed that a highly significant negative correlation was observed between the total dry matter and the leaf curl disease incidence at 60 DAS and maturity and a non-significant correlation was observed at 20 DAS and 40 DAS. A highly significant negative correlation was observed between thrips population and total dry matter at 60 DAS and maturity and a non-significant association was observed at 20 DAS and maturity (Table 5). Dry mass was the only morphological trait significantly correlated with thrips damage in tomato (González, 1974)

Total dry matter accumulation was significantly higher in resistant genotypes indicating that the resistant genotypes were less affected by leaf curl disease caused by GBNV. The susceptible genotypes showed a significant reduction in the total dry matter of the plants. A decrease in the total dry biomass of the plants was observed in that tomato plants infected with yellow mosaic virus (Cladwell, 1934). CMV and BICMV infection has significantly reduced the leaf, stem, pod root ant total dry mass of cowpea varieties (Pio-Ribeiro *et al.,* 1978).

The dry matter accumulation and other four tolerance indicators confirmed antixenosis for the genotype FEB 1115 variety of soybean against thrips (Andrea, 2004). In peanut genotypes the thrips incidence has a lower but negative association with a total dry matter of plant (Ekvised *et al.,* 2006). Soybean genotypes infected with soybean mosaic virus SMV were observed having reduced leaf, stem and root dry weights and severe reduction when infected early (Hema *et al.,* 2015). In groundnut, the plants infected by BICV has reduced the total fresh and dry weights of the plants significantly (Ibrahim *et al.,* 2017). The *begomovirus* infection in chilli genotype has reduced the shoot, root, stem and total dry matter in susceptible genotypes.

From the experiment it can be concluded that the leaf curl disease has severely affected the plant growth, development and dry matter partitioning efficiency and screening of genotypes based on the dry matter partitioning and accumulating under naturally epidemic conditions gives the agronomic and physiological performance of those genotypes. The genotype TU 40 showed higher partitioning efficiency.

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