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Evaluation of blackgram (*Vigna mungo* L. Hepper) genotypes for growth parameters under imposed moisture stress condition

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Abstract
A field experiment was conducted at the experimental field twelve blackgram genotypes under moisture stress condition. A wide diversity among the genotypes in their growth parameters was recorded. Genotypes varied from genotypes TBG-104, KU-12-13 and KU-12-37 showed higher values of Crop growth rate, Net assimilation rate, leaf area index and leaf area duration during moisture stress condition than irrigated condition. TBG-104 and KU-12-13 recorded significantly higher values in both irrigated as well as stress conditions, which denotes the ability of these genotypes was sustained under severe moisture stress at pod filling stage of crop. Whereas LBG-752 and LBG 20 recorded lower values of CGR and NAR as well as NDU 12-300 and KU 12-14 showed lowest values of LAI and LAD during both rabi 2015-16 and rabi 2016-17.

Keywords: Moisture stress, blackgram, CGR, NAR, LAI and lad

Introduction
Among the various pulses, blackgram or urdbean (*Vigna mungo* [L.] Hepper) is an important grain legume with easily digestible protein. It belongs to the family fabaceace with 2n=22. Blackgram grain contains about 25 per cent protein, 56 per cent carbohydrate, 2 per cent fat, 4 per cent minerals and 0.4 per cent vitamins. *Vigna mungo* (L.) Hepper, commonly known as blackgram, contributes 20% to overall world pulse production (Saravanakumar *et al.*, 2007) [10]. In India, blackgram is cultivated in an area of 761.3 thousands of hectares, with a production of 678.6 thousand tonnes and with the productivity of 891.0 kg ha^{-1}.However, production of blackgram is adversely affected by various environmental stress factors, especially drought that reduce yield (Pandey *et al.*, 2014) [8]. Soil moisture stress is a major hazard for successful crop production throughout the world.

Drought stress is considered to be a moderate loss of water, which leads to stomatal closure and limitation of gas exchange. It disturb the turgor pressure in cells altering the physiological and biochemical processes, disrupting cell membrane and ultrastructure of subcellular organelles (Yordanov *et al*., 2003) [13]. It impairs root cell development, nutrient uptake and affects photosynthesis; hence, affect growth and development of plant (Dhole and Reddy, 2010) [3].

Materials and Methods
The experiment was laid out in a split plot design with two main treatments, twelve sub treatments and replicated thrice. Main Treatments: 2: i) Irrigated (control) ii) Impose moisture stress at 60-80 DAS, Sub Treatments (12 Genotypes) KU -12-55, LBG-623, LBG-680, NDU-12-300, LBG-685, KU-12-14, LBG-645, KU-12-37, TBG-104, KU-12-33, LBG-752 and LBG-20. Following growth parameters are recorded every 15 days interval up to harvest in both *Rabi* 2015-16 and *Rabi* 2016-17.

Crop growth rate (g m^{-2} day^{-1})
The CGR is the rate of dry matter production per unit ground area per unit time. It is used for the estimation of production efficiency of crop. The CGR was calculated adopting the formula as suggested by Watson (1952) [12].

$$CGR = \frac{(W_2 - W_1)}{(t_2 - t_1)} \times \frac{1}{P}$$

Where, W_1 and W_2 are total dry weight of plant at times t_1 and t_2 and P is the land area.

Net assimilation rate (g dm^{-2} week^{-1})

The NAR is the measure of amount of photosynthetic product getting accumulated per unit leaf area per unit time. It is an estimate of net photosynthesis. It is the rate of increase in dry matter per unit leaf area per unit time. It was calculated by using formula suggested by Gregory (1926) [4].

$$NAR = \frac{(\log_e A_2 - \log_e A_1)}{(A_2 - A_1)} \times \frac{(W_2 - W_1)}{(t_2 - t_1)}$$

Where, W_1 and W_2 are the total plant dry weight and A_1 and A_2 are leaf area at times t_1 and t_2.

Leaf area index (LAI)

The leaf area index was calculated by dividing the total leaf area with the corresponding ground area as suggested by Watson (1952) [12].

$$LAI = \frac{\text{Leaf area}}{\text{Ground area}}$$

Leaf area duration (Days)

LAD expresses in qualitative terms as to how long a crop maintain its active assimilatory tissue i.e. leaves

$$LAD = \frac{(LAI_1 + LAI_2)(t_2 - t_1)}{2}$$

Where,
LAI_1 = Leaf area index at time interval t_1 and
LAI_2 = Leaf area index at time interval t_2

Results and Discussion

Irrespective of treatment, the CGR increased in all the genotypes under irrigated and moisture stress conditions upto 45-60 DAS and thereafter decreased up to harvest. Significant differences were observed between moisture stress treatments, genotypes and their interactions throughout the growth stages in both the years of testing. Similar results were also reported in groundnut (Pranusha, 2012) [9] and mungbean (Uddin *et al*., 2013) [11].

The imposed moisture stress from pod formation to pod filling stage i.e. from 40-60 DAS caused significant reduction in CGR. The extent of decrease was 23.6 and 18.0 per cent at 30-.45 DAS, 54.1 and 56.9 at 45-60 DAS and 33.4 and 38.62 at 60-75 DAS in both years compared to respective irrigated treatments.

Among the genotypes, TBG-104 and KU-12-13 recorded significantly higher CGR compared to other genotypes. These genotypes sustained crop growth under moisture stress conditions than other entries. NDU-12-300, LBG-752 and LBG-20 recorded lowest CGR, whereas KU-12-37, LBG-645, LBG-623and KU-12-55 recorded moderate crop growth rate. TBG-104 and KU-12-13 showed their superiority in growth rates over other entries during both seasons of testing (Table 1A and 1B).

Moisture stress from 40-60 DAS significantly decreased NAR values. The extent of decrease was 38.1 and 42.3 per cent at 45-60 DAS in both the years of testing. Similar results were reported in pigeonpea (Kamaldeep *et al*., 2004) and mungbean (Uddin *et al*., 2013) [11]. The genotypes TBG-104 and KU-12-13 also recorded higher NAR, along with CGR values, whereas KU-12-14, KU-12-37, LBG-685, NDU-12-300 and LBG-623 recorded moderate NAR whereas LBG-752 and LBG-20 recorded low NAR similar to CGR values (Table 2A and 2B).

Net assimilation rate, an indirect measurement of photosynthetic activity was affected in moisture stress at pod formation compared to irrigated treatment, similar to crop growth rate. Decreased crop growth rates and NAR can be attributed to poor dry matter accumulation and partitioning in moisture stress conditions. These results, further establishes superiority of TBG-104 and KU-12-13 maintaining higher photosynthetic activity under irrigated as well as moisture stress conditions. This ability in maintaining higher photosynthetic activity even under stress conditions compared to other genotypes which shows their capabilities in sustaining chloroplast activity and photosynthesis at moisture stress conditions.

LAI showed significant differences 45 DAS to 75 DAS between treatments and genotypes and their interactions in both the years. Similar significance difference were observed in blackgram (Mate et al., 2003). Leaf area index increased upto 45 DAS and declined thereafter. Significantly decreased mean leaf area index due to imposition of moisture stress treatment 18.9 and 20.0 per cent at 45 DAS and 32.0 and 33.3 per cent at 60 DAS compared to irrigated treatment in both years. Similar results were found in groundnut (Kaul, 1999 and Antony, 2000) [6].

Among the blackgram genotypes KU-12-13 recorded higher LAI under moisture stress as well as irrigated conditions followed by TBG-104 and KU-12-37 throughout growing season. These results further establish the superiority of KU-12-13, TBG-104 and KU-12-37 in maintaining higher green leaf area both under irrigated and moisture stress conditions. Whereas NDU-12-300 recorded lowest leaf area index during both *Rabi* 2016 and *Rabi* 2017 (Fig 1A and 1B).

Moisture stress at pod formation stage to pod filling i.e. from 40-60 DAS significantly decreased mean LAD to the extent of 25.1 and 27.8 per cent at 45-60 DAS and 32.8 and 33.3 per cent at 60-75 DAS and similar results were reported in chickpea (Ozalkan *et al*. 2010) [7].

Similar to LAI, KU-12-13, TBG-104 and KU-12-37 maintained higher LAD, than other genotypes (Fig 2A and 2B). NDU-12-300 and KU-12-14 recorded lower LAD. The superior genotypes KU-12-13, TBG-104 and KU-12-37 also posses the higher leafyness specially at grain filling stage compared to other genotypes and thus proved efficient in current photosynthesis. Leaf area duration indicates maintenance of photo synthetically active green leaf area for longer time in crop duration of a genotype. It is an useful growth parameter indicating the efficiency of photosynthetic system, with a high degree of association with dry matter accumulation (Chetti and Sirohi, 1995) [2]. Higher LAD specially during seed filling stage has profound influence on yield and its attributes

Table 1A: Screening of blackgram genotypes for crop growth rate (g m^{-2}. day^{-1}) under imposed moisture stress condition during *rabi* 2015-16

	15 -30 DAS			30-45 DAS			45-60 DAS			60-75 DAS		
Genotypes	**M_0**	**M_1**	**Mean**	**M_0**	**M_1**	**Mean**	**M_0**	**M_1**	**Mean**	**M_0**	**M_1**	**Mean**
KU-12-55	5.00	5.18	5.09	6.34	2.83	4.58	13.84	4.74	9.29	2.93	4.49	3.71
LBG-623	5.52	6.50	6.01	8.13	8.41	8.27	13.94	5.84	9.89	9.84	5.22	7.53
LBG-680	4.10	4.66	4.38	13.47	7.36	10.42	20.52	7.15	13.84	0.59	2.50	1.55
NDU-12-300	6.32	7.24	6.78	2.89	0.99	1.94	14.90	6.24	10.57	6.41	0.84	3.62
LBG-685	4.65	5.81	5.23	9.16	8.07	8.62	15.44	8.04	11.74	0.47	0.98	0.72
KU-12-14	4.43	5.55	4.99	9.52	7.34	8.43	14.03	6.15	10.09	2.88	0.22	1.55
LBG-645	4.24	4.70	4.47	7.59	8.87	8.23	15.81	7.81	11.81	4.81	0.08	2.44
KU-12-37	5.16	5.37	5.27	10.90	10.04	10.47	24.81	12.18	18.50	1.67	0.36	1.01
TBG-104	4.81	5.41	5.11	16.52	16.75	16.64	18.58	7.84	13.21	2.47	5.53	4.00
KU-12-13	5.31	5.92	5.61	16.43	15.52	15.98	19.22	8.33	13.78	2.13	3.73	2.93
LBG-752	6.46	6.47	6.46	11.21	4.16	7.68	13.90	9.32	11.61	0.81	0.22	0.52
LBG-20	5.78	7.93	6.85	11.47	3.94	7.71	17.39	9.13	13.26	1.62	0.24	0.93
Mean	5.15	5.89		10.30	7.86		16.86	7.73		3.05	2.03	
	T	G	T × G	T	G	T × G	T	G	T × G	T	G	T × G
SE m ±	0.013	0.015	0.045	0.054	0.44	0.18	0.06	0.58	0.23	0.052	0.160	0.182
CD (P=0.05)	0.08	0.04	0.08	0.33	1.25	1.79	0.481	1.66	2.37	0.325	0.456	0.687

M_0: Irrigated (control), M_1: Moisture stress

Table 1B: Screening of blackgram genotypes for crop growth rate (g m^{-2}.day^{-1}) under imposed moisture stress condition during *Rabi* 2016-17

	15 -30 DAS			30-45 DAS			45-60 DAS			60-75 DAS		
Genotypes	**M_0**	**M_1**	**Mean**	**M_0**	**M_1**	**Mean**	**M_0**	**M_1**	**Mean**	**M_0**	**M_1**	**Mean**
KU-12-55	4.33	4.31	4.32	7.38	5.40	6.39	12.31	1.96	7.13	0.07	4.96	2.51
LBG-623	5.68	5.69	5.68	4.93	8.98	6.95	15.71	4.73	10.22	9.24	4.27	6.75
LBG-680	3.78	4.46	4.12	14.49	6.33	10.41	18.15	7.60	12.88	0.47	2.27	1.37
NDU-12-300	5.47	5.87	5.67	3.07	1.89	2.48	14.24	4.89	9.57	6.49	1.67	4.08
LBG-685	4.86	5.09	4.97	7.42	7.89	7.65	15.22	7.11	11.17	0.82	0.18	0.50
KU-12-14	4.30	4.53	4.41	8.35	7.04	7.70	11.98	6.38	9.18	4.78	0.27	2.52
LBG-645	4.13	4.04	4.09	7.62	8.69	8.15	14.07	5.95	10.01	5.04	0.60	2.82
KU-12-37	5.02	5.27	5.15	9.44	9.20	9.32	17.93	7.91	12.92	6.00	3.04	4.52
TBG-104	4.32	5.11	4.71	16.40	15.75	16.08	15.89	7.42	11.65	4.44	6.84	5.64
KU-12-13	6.24	6.52	6.38	14.64	14.58	14.61	15.09	7.58	11.33	5.51	3.42	4.47
LBG-752	6.29	5.89	6.09	10.69	4.42	7.55	12.62	8.31	10.47	1.16	0.13	0.64
LBG-20	5.78	7.47	6.63	10.40	3.96	7.18	17.55	8.04	12.80	1.31	0.20	0.76
Mean	5.02	5.35		9.57	7.84		15.06	6.49		3.78	2.32	
	T	G	T × G	T	G	T × G	T	G	T × G	T	G	T × G
SE m ±	0.005	0.016	0.018	0.059	0.42	0.20	0.086	0.515	0.299	0.05	0.17	0.20
CD (P=0.05)	0.034	0.046	0.070	0.369	1.21	1.74	0.534	1.46	2.11	0.36	0.49	0.74

Table 2A: Screening of blackgram genotypes for net assimilation rate (g dm^{-2}week^{-1}) under imposed moisture stress condition during *Rabi* 2015-16

	15 -30 DAS			30-45 DAS			45-60 DAS			60-75 DAS		
Genotypes	**M_0**	**M_1**	**Mean**	**M_0**	**M_1**	**Mean**	**M_0**	**M_1**	**Mean**	**M_0**	**M_1**	**Mean**
KU-12-55	0.0114	0.0142	0.0128	0.0051	0.0017	0.0034	0.0060	0.0025	0.0042	0.0015	0.0030	0.0023
LBG-623	0.0101	0.0121	0.0111	0.0048	0.0040	0.0044	0.0041	0.0026	0.0034	0.0034	0.0028	0.0031
LBG-680	0.0071	0.0079	0.0075	0.0074	0.0041	0.0058	0.0056	0.0035	0.0046	0.0002	0.0018	0.0010
NDU-12-300	0.0146	0.0166	0.0156	0.0039	0.0008	0.0023	0.0084	0.0042	0.0063	0.0039	0.0008	0.0023
LBG-685	0.0095	0.0107	0.0101	0.0073	0.0052	0.0063	0.0058	0.0048	0.0053	0.0002	0.0005	0.0004
KU-12-14	0.0101	0.0117	0.0109	0.0094	0.0053	0.0074	0.0077	0.0036	0.0057	0.0016	0.0001	0.0009
LBG-645	0.0089	0.0090	0.0090	0.0055	0.0039	0.0047	0.0039	0.0031	0.0035	0.0011	0.0000	0.0006
KU-12-37	0.0089	0.0091	0.0090	0.0071	0.0043	0.0057	0.0055	0.0041	0.0048	0.0005	0.0002	0.0003
TBG-104	0.0100	0.0105	0.0102	0.0078	0.0068	0.0073	0.0054	0.0023	0.0039	0.0009	0.0021	0.0015
KU-12-13	0.0094	0.0102	0.0098	0.0086	0.0064	0.0075	0.0047	0.0022	0.0034	0.0006	0.0014	0.0010
LBG-752	0.0107	0.0110	0.0109	0.0063	0.0018	0.0041	0.0042	0.0036	0.0039	0.0003	0.0001	0.0002
LBG-20	0.0084	0.0114	0.0099	0.0064	0.0017	0.0041	0.0047	0.0036	0.0042	0.0005	0.0001	0.0003
Mean	0.0099	0.0112		0.0066	0.0038		0.0055	0.0034		0.0012	0.0011	
	T	G	T × G	T	G	T × G	T	G	T × G	T	G	T × G
SE m ±	0.00001	0.00001	0.0001	0.00001	0.0003	0.0001	0.00001	0.0002	0.00001	0.0001	0.0001	0.0003
CD (P=0.05)	0.0001	0.0001	0.0002	0.0002	0.0007	0.0010	0.0001	0.0006	0.0008	N.S	0.0002	0.0004

M_0: Irrigated (control), M_1: Moisture stress

Table 2B: Screening of blackgram genotypes for net assimilation rate (g dm^{-2} week^{-1}) under imposed moisture stress condition during *rabi* 2016-17

	15 -30 DAS			30-45 DAS			45-60 DAS			60-75 DAS		
Genotypes	**M_0**	**M_1**	**Mean**	**M_0**	**M_1**	**Mean**	**M_0**	**M_1**	**Mean**	**M_0**	**M_1**	**Mean**
KU-12-55	0.0106	0.0120	0.0113	0.0049	0.0039	0.0044	0.0058	0.0011	0.0034	0.0000	0.0036	0.0018
LBG-623	0.0118	0.0125	0.0121	0.0023	0.0056	0.0040	0.0047	0.0022	0.0035	0.0033	0.0024	0.0028
LBG-680	0.0076	0.0087	0.0081	0.0083	0.0040	0.0062	0.0052	0.0043	0.0047	0.0001	0.0017	0.0009
NDU-12-300	0.0139	0.0138	0.0138	0.0025	0.0015	0.0020	0.0085	0.0036	0.0060	0.0044	0.0017	0.0030
LBG-685	0.0108	0.0106	0.0107	0.0040	0.0067	0.0054	0.0060	0.0046	0.0053	0.0004	0.0001	0.0003
KU-12-14	0.0108	0.0100	0.0104	0.0074	0.0061	0.0068	0.0069	0.0042	0.0055	0.0030	0.0002	0.0016
LBG-645	0.0096	0.0086	0.0091	0.0041	0.0046	0.0044	0.0036	0.0026	0.0031	0.0012	0.0004	0.0008
KU-12-37	0.0094	0.0098	0.0096	0.0034	0.0042	0.0038	0.0042	0.0028	0.0035	0.0020	0.0014	0.0017
TBG-104	0.0097	0.0110	0.0104	0.0080	0.0077	0.0079	0.0049	0.0024	0.0036	0.0018	0.0029	0.0023
KU-12-13	0.0114	0.0118	0.0116	0.0062	0.0063	0.0062	0.0038	0.0021	0.0030	0.0016	0.0014	0.0015
LBG-752	0.0106	0.0105	0.0106	0.0046	0.0020	0.0033	0.0040	0.0033	0.0037	0.0005	0.0001	0.0003
LBG-20	0.0097	0.0114	0.0105	0.0043	0.0019	0.0031	0.0051	0.0033	0.0042	0.0004	0.0001	0.0003
Mean	0.0105	0.0109		0.0050	0.0046		0.0052	0.0030		0.0016	0.0013	
	T	G	T × G	T	G	T × G	T	G	T × G	T	G	T × G
SE m ±	0.00001	0.00002	0.00001	0.00001	0.0002	0.0001	0.00001	0.0002	0.0001	0.00001	0.0001	0.0001
CD (P=0.05)	0.0001	0.0001	0.0001	0.0002	0.0007	0.0010	0.0001	0.0006	0.0008	0.0002	0.0003	0.0004

M0: Irrigated (control), M1: Moisture stress

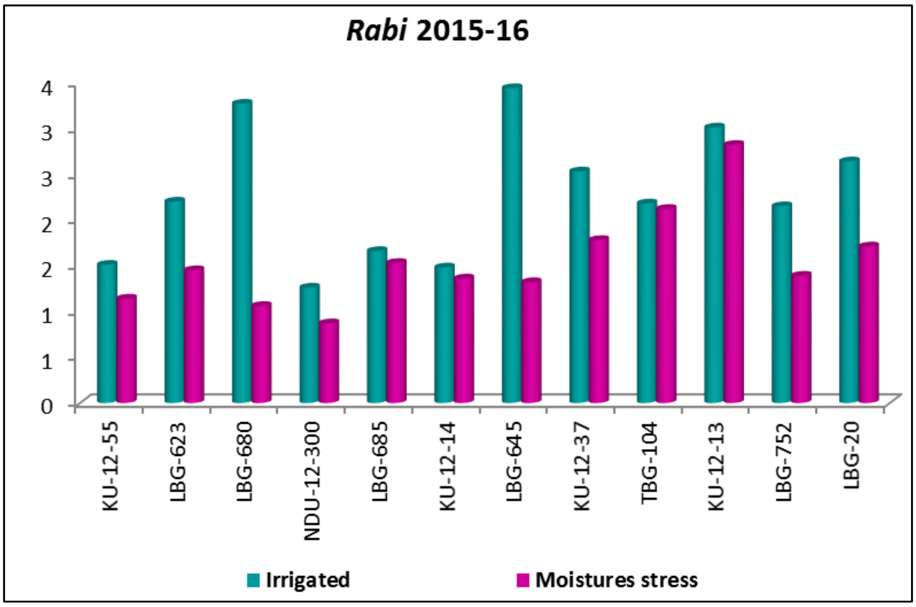

Fig 1A: Evaluation of blackgram genotypes for leaf area index under imposed moisture stress condition during *Rabi* 2015-16 at 60 DAS

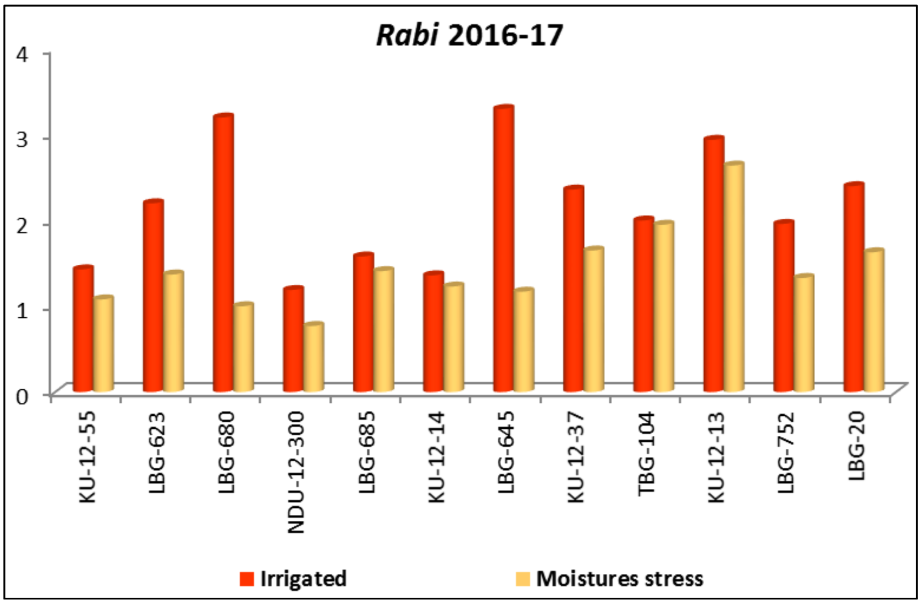

Fig 1B: Evaluation of blackgram genotypes leaf area index under imposed moisture stress condition during *Rabi* 2016-17 at 60 DAS

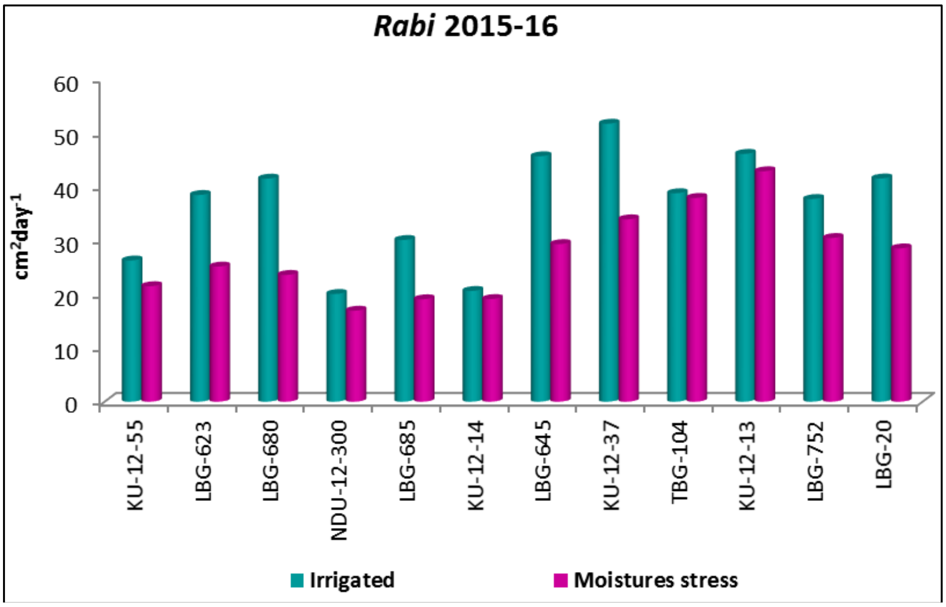

Fig 2A: Evaluation of blackgram genotypes for leaf area duration ($cm^2 day^{-1}$) under imposed moisture stress condition during *Rabi* 2015-16 at 45-60 DAS

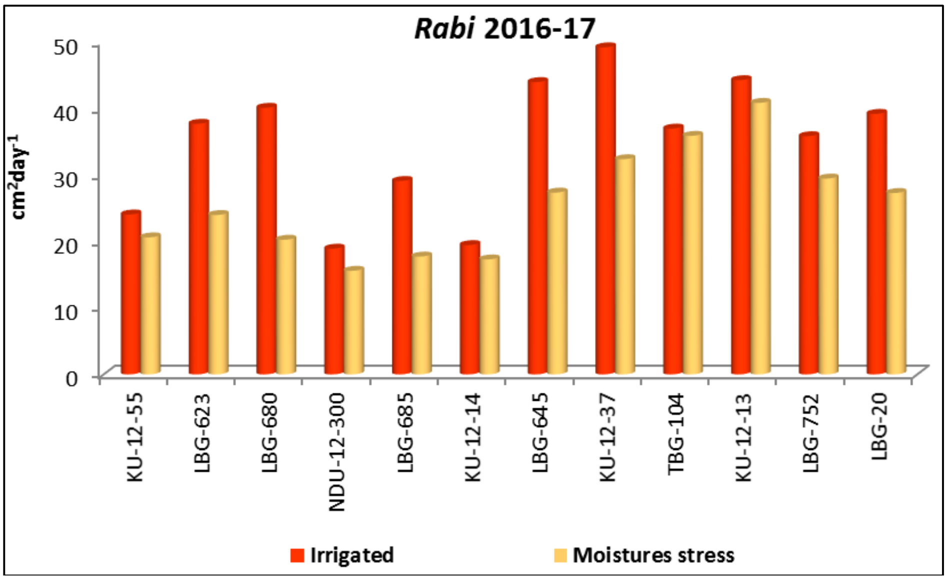

Fig 2B: Evaluation of blackgram genotypes leaf area duration ($cm^2 day^{-1}$) under moisture stress condition during *Rabi* 2016-17 at 45-60 DAS

Conclusion

During both the years of experimentation the tested genotypes were significantly varied for CGR, NAR, LAI and LAD were affected due to imposition of moisture stress at 40-60 DAS compared to irrigated control. The genotypes, TBG-104, KU-12-13, KU-12-37, LBG-623 which maintained higher leaf area and dry matter also recorded higher growth and physiological traits compared to other entries. Susceptible genotype NDU-12-300 and KU12-14 showed poor performance

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