RESEARCH ARTICLE Legume Research- An International Journal, Volume 44 Issue 10: 1226-1232 (October 2021)

Effect of Simulated Waterlogging Condition Imposed at Early Vegetative Growth on Final Yield in Greengram (*Vigna radiata*)

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ABSTRACT

Background: 'Rain' plays a very important role since most of the agricultural productivity is rainfall dependent. However at the same time unpredictable and untimely rainfall are also responsible for crop loss. In India, our North-eastern region receives the highest amount of rainfall. Even in pre-monsoon season, our region receives very high amount of rainfall which hampers the crop production, especially the summer season greengram. Hence, an effort had been made to screen some genotypes of summer greengram, tolerant to waterlogging condition. A study was carried out during the summer season to evaluate the physiological performance of some greengram genotypes as influenced by waterlogging condition of varying duration imposed at early vegetative stage of growth.

Methods: From an initial screening of forty genotypes in laboratory condition, five genotypes were selected based on germination percentage, seedling length and vigour index. These five genotypes were further evaluated in a pot experiment with four treatment combinations comprising of control (T1), waterlogging for 4 days (T2), waterlogging for 8 days (T3) and waterlogging for 12 days (T4). Waterlogging conditions were created in the pots at the time of sowing.

Result: Water logging caused adverse effect on growth and development of all the genotypes, with the longest waterlogging showing severe deleterious effect. The parameters *viz.* germination percentage, leaf chlorophyll content, leaf area, plant height, nitrate reductase activity, number of seeds pod^{-1}, pods plant^{-1}, root length, number of root nodules plant^{-1} and harvest index were found to decline under waterlogged condition whereas, lipid peroxidase and superoxide dismutase activity showed higher values under waterlogged condition. The performance of the genotype Sadiya Local was found to be the best from the point of view of tolerance as indicated by higher seed yield followed by AKM 12-28. The better performance of this genotype appeared to be related to the higher values for some traits *viz.* germination percentage, leaf chlorophyll, nitrate reductase activity, superoxide dismutase activity, number of pods plant^{-1} and harvest index.

Key words: Genotypes, Greengram, Lipid peroxidase, Nitrate reductase, Waterlogging.

INTRODUCTION

Mungbean is the third most popular pulse crop after chickpea and pigeon pea cultivated throughout India. Mungbean is reported to be unable to withstand waterlogging, particularly during the early stages of growth (Singh and Singh, 2011). The T-44 is waterlogging tolerant genotype of greengram. Pre-monsoon showers greatly influence the production of the summer season greengram. Waterlogging is known to inhibit growth, flowering and yield of several plant species which may be accompanied by poor uptake of water and minerals from the soil (Troughtand Drew, 1980), senescence and abscission of leaves (Kozlowski, 1976) and derangement in the hormonal metabolism of the plant (Crozier *et al.,* 1969).

In India, north-eastern region receives the highest amount of rainfall in a year *i.e.* more than 2250 mm. During the time of pre-monsoon season also, this region receives very large amount of rainfall. Data of last seven years (2013-2019) indicate that during January to May on an average the total amount of rainfall received in Assam ranges between 450-800 mm. As the recommended time for sowing for summer greengram in Assam is between mid-February to mid-March, the summer sown crops is mostly affected by the water stagnation and water saturation during sowing and early seedling establishment.

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How to cite this article: Saikia, B., Kalita, P. and Das, R. (2021). Effect of Simulated Waterlogging Condition Imposed at Early Vegetative Growth on Final Yield in Greengram (*Vigna radiata*). Legume Research. 44(10): 1226-1232. DOI: 10.18805/LR-4238.

Submitted: 18-09-2019 **Accepted:** 22-08-2020 **Online:** 02-01-2021

In mungbean, waterlogging leads to poor germination of seeds. Even the seeds which germinated they show very poor growth and development, thus, showing the adverse effect of waterlogging during the early seedling establishment stage include reproductive stage. According to Jackson (1983), diffusion of oxygen through water is 104 times slower than in air. Roots in waterlogged soils frequently die of anoxia (Alam *et al*., 2010). Lack of nitrogen in certain leguminous species due to poor nitrogen fixation under waterlogged condition is also found (Laosuwan *et al.,* 1994). The extent of injury due to waterlogging depends upon the genotypes, environmental conditions, stage of development and the duration of stress (Choi *et al*., 1986).

MATERIALS AND METHODS

In order to assess the performance of greengram genotypes in terms of morphological, physiological and yield parameters under simulated waterlogging a study was carried out in the Stress Physiology Laboratory premises, Department of Crop Physiology, Assam Agricultural University, Jorhat-13 during summer season of 2018. Initially forty greengram genotypes were screened under laboratory condition in petri-plates lined with filter paper by creating waterlogging condition for 1, 2 and 4 days respectively including the control. The parameters used for screening were germination percentage, plumule length, radical length and vigour index. Five greengram genotypes namely NVL-855, KM 2355, AKM 12-28, Sadiya Local and Pratap were selected from the initial screening for their further evaluation under field conditions. The genotypes were collected from KVK Andro village (Manipur), Sadiya (Assam) and Instruction cum research farm (I.C.R Farm) of AAU, Jorhat. The seeds were sown in plastic pots (30 × 30 cm) containing dry soil. Prior to filling up the pots, the soil was mixed thoroughly with FYM in the ratio of 3:1 and the required amount of fertilizers (N, P, K) was mixed. There were four treatments namely control (T1), waterlogging for 4 days (T2), waterlogging for 8 days (T3) and waterlogging for 12 days (T4). The experimental design adopted was factorial completely randomized design (Factorial CRD) with three replications. The observations on germination percentage was recorded at 12 DAS and other physiological and biochemical parameters like total chlorophyll, nitrate reductase, lipid peroxidase, superoxide dismutase, plant height and leaf area were recorded after a recovery period of 20 days whereas the yield parameters like seed yield plant^{-1}, number of pods plant^{-1}, number of seeds plant^{-1} and harvest index were recorded at the time of harvest.

The seedlings with about 2 mm plumule were considered as germinated and the magnitudes of germination were expressed in the terms of percentage. The total chlorophyll content in leaf tissue was estimated by DMSO method as suggested by Hiscox and Israelstam (1979). The other biochemical parameters like nitrate reductase activity (Thimmaiah, 1999), superoxide dismutase activity (Beauchamp and Fridovich, 1971) and lipid peroxidase (Heath and Packer, 1968) were estimated by standard protocols after 20 days of recovery period from termination of water logging. Data on yield parameters were recorded at the time of harvesting. Harvest index was calculated by the formula given by Nichi Provinch (1967). Statistical analysis of data was done following the method of analysis of variance (ANOVA) as suggested by Panse and Sukhatme (1967). The critical difference (CD) values were calculated at 5 percent probability level.

RESULTS AND DISCUSSION

Germination percentage

From the Table 1, it was found that with increase in the durations of the waterlogging stress, the germination percentage was decrease further. In control, the highest germination percentage was observed whereas the lowest value was recorded in the treatment where the waterlogging stress was imposed for 12 days. Among the genotypes, Sadiya Local showed the highest germination percentage followed by Pratap, AKM 12-28 and the lowest germination percentage was recorded by KM 2355. Reduction in germination percentage may be causally related to the over soaking of the seeds under waterlogged conditions resulting in leaching out of some useful biochemicals which might result in the reduction of the viability and vigour of the seeds. Hsu *et al*. (2000) indicated that the emergence ability of Sudangrass was reduced by waterlogging after sowing. Lal *et al*. (2018) found that waterlogging treatment resulted in a 0 to 75% decline in per cent survivality of the plants.

Total chlorophyll

With increased duration of applied waterlogging stress created, the total leaf chlorophyll content decreased further (Table 2). The highest decrease in total leaf chlorophyll content was found in the situation where 12 days of waterlogging was maintained. Averaging over all the genotype Sadiya Local showed the highest total leaf chlorophyll content and in this genotype per cent reduction in total chlorophyll content over control was also found to be lowest. Waterlogging at early vegetative stage caused decrease in total leaf chlorophyll content by 46.7 per cent. The decrease in chlorophyll content under waterlogged conditions might be due to increased chlorophyll degradation and also due to decrease chlorophyll synthesis. Similar reports of the influence of waterlogging had also been published in greengram by Vijayarengan and Dhanavel, (2005) and Kumar *et al*. (2013).

Nitrate reductase

With increase in duration of applied waterlogging stress, nitrate reductase activities of the leaf was found to decreased proportionately as we had observed in Table 2. Waterlogging for twelve days showed the highest decreased in nitrate reductase activity. The highest value of leaf nitrate reductase activity was found in the genotype AKM 12-28 followed by Sadiya Local. In the genotype Sadiya Local the per cent decrease over control was found to be the lowest. Reduction in nitrate reductase activity in leaf might be due to decrease

Table 1: Germination percentage measured at 12 DAS.

Genotypes	T1	T2	T3	T4	Mean
NVL-855	80.00	75.00	65.00	60.00	70.00
KM 2355	75.00	70.00	50.00	45.00	60.00
AKM 12-28	85.00	70.00	60.00	50.00	66.25
Pratap	80.00	75.00	50.00	45.00	62.50
Sadiya Local	90.00	75.00	70.00	65.00	75.00
Mean	82.00	73.00	59.00	53.00	
	SE d ±	**CD-5%**			
V	4.541	9.540			
T	4.062	8.533			
V × T	9.083	NS			

Table 2: Total chlorophyll and nitrate reductase of leaves measured after 20 days of recovery period.

Genotypes	Total leaf chlorophyll content (mg chl.g^{-1} fresh wt.)					Nitrate reductase activity (µ mole NO_3^- g^{-1} hr^{-1})				
	T1	T2	T3	T4	Mean	T1	T2	T3	T4	Mean
NVL-855	2.92	2.16	1.66	1.35	2.02	5.44	5.01	4.58	4.05	4.77
KM 2355	3.12	2.42	1.88	1.27	2.17	5.09	4.75	4.42	4.03	4.57
AKM 12-28	3.15	2.78	2.37	1.78	2.52	5.28	4.95	4.80	4.51	4.88
Pratap	3.04	2.79	2.24	1.82	2.47	5.18	4.90	4.40	4.18	4.66
Sadiya Local	3.29	3.15	2.81	2.05	2.82	5.26	5.01	4.68	4.49	4.86
Mean	3.10	2.66	2.19	1.65		5.25	4.93	4.58	4.25	
	SE d ±	**CD-5%**				**SE d ±**	**CD-5%**			
V	0.051	0.107				0.146	NS			
T	0.046	0.096				0.131	0.271			
V × T	0.102	0.214				0.292	NS			

Table 3: Superoxide dismutase activity and lipid peroxidase activity of roots measured after 20 days of recovery period.

Genotypes	SOD activity of roots (mg^{-1} protein)					Lipid peroxidase activity of roots (MDA n mole g^{-1} fresh wt.)				
	T1	T2	T3	T4	Mean	T1	T2	T3	T4	Mean
NVL-855	1.02	1.18	1.46	1.68	1.33	3.37	3.97	4.17	4.99	4.12
KM 2355	1.63	1.79	1.93	2.01	1.84	4.21	4.72	5.15	6.01	5.02
AKM 12-28	2.03	2.19	2.66	2.74	2.40	4.70	4.87	5.06	5.89	5.13
Pratap	1.67	2.02	2.39	2.58	2.16	4.61	5.00	5.21	5.84	5.16
Sadiya Local	1.37	2.00	2.45	2.83	2.16	4.89	4.93	5.14	6.07	5.26
Mean	1.54	1.83	2.17	2.37		4.35	4.70	4.94	5.76	
	SE d ±	**CD-5%**				**SE d ±**	**CD-5%**			
V	0.110	0.231				0.061	0.128			
T	0.098	0.206				0.055	0.115			
V × T	0.220	NS				0.122	0.207			

Table 4: Plant height and leaf area measured at 20 days of recovery period.

Genotypes	Plant height (cm)					Leaf area $plant^{-1}$(cm^2)				
	T1	T2	T3	T4	Mean	T1	T2	T3	T4	Mean
NVL-855	43.65	41.10	39.50	35.50	39.93	282.38	257.77	243.32	239.84	255.82
KM 2355	44.05	41.90	39.35	36.75	40.51	318.16	311.26	301.05	281.56	303.01
AKM 12-28	43.65	41.05	39.85	37.70	40.56	241.67	239.61	225.69	215.79	230.69
Pratap	42.75	40.00	37.50	35.50	38.93	364.06	352.68	329.29	319.18	341.30
Sadiya Local	41.45	40.05	39.15	37.00	39.41	256.11	253.99	240.75	229.64	245.12
Mean	43.11	40.82	39.07	36.49		292.47	283.06	268.02	257.20	
	SE d ±	**CD-5%**				**SE d ±**	**CD-5%**			
V	0.362	0.760				1.666	3.501			
T	0.324	0.680				1.491	3.131			
V × T	0.724	NS				3.333	7.001			

in nitrate import from roots. Nitrate induces activation and induction of nitrate reductase. Thus, the observed decrease of nitrate reductase activity in leaves could be related to a low nitrate translocation from the damaged root system (Alaousi-Sosse *et al*., 2005).

Superoxide dismutase

With increase in duration of applied waterlogging stress at early vegetative stage, superoxide dismutase activities of the roots were found to have increased further (Table 3). Among the genotype, AKM 12-28 exhibited the highest superoxide dismutase activity and in the genotype Sadiya Local the per cent increase over control was found to be highest. Waterlogging at early vegetative stage increased superoxide dismutase activity by 53.1 per cent compared to control. Super oxide dismutase is a naturally occurring enzyme in plants, which protects cells from oxidative damage. Increased SOD activity may be due to increase in antioxidant responses of plant under waterlogged conditions. Increase in SOD activity under waterlogged condition has been reported in pigeonpea by Kumutha *et al*. (2009) and in mungbean by Bansal *et al*. (2019).

Table 5: Root length, root volume and number of root nodules measured after 20 days of recovery period.

Genotypes	Root length (cm)					Root volume (ml)					Number of root nodules				
	T1	T2	T3	T4	Mean	T1	T2	T3	T4	Mean	T1	T2	T3	T4	Mean
NVL-855	14.39	13.41	12.78	11.26	12.96	2.82	2.71	2.44	2.21	2.54	29.36	28.11	26.02	24.10	26.90
KM 2355	13.80	13.39	12.97	11.44	12.90	2.83	2.60	2.41	2.31	2.53	26.55	26.09	23.77	23.35	24.94
AKM 12-28	12.38	12.18	11.67	11.24	11.87	2.70	2.63	2.42	2.29	2.51	31.62	30.87	30.58	29.49	30.64
Pratap	14.75	13.95	13.31	11.82	13.45	3.12	3.01	2.65	2.43	2.80	29.19	27.83	25.03	23.06	26.28
Sadiya Local	11.92	11.76	11.42	10.65	10.98	2.54	2.46	2.39	2.26	2.41	26.63	26.59	25.86	24.00	25.77
Mean	13.41	12.97	12.22	11.13		2.80	2.67	2.47	2.36		28.67	27.90	26.25	24.80	
	SE d ±	**CD-5%**				**SE d ±**	**CD-5%**				**SE d ±**	**CD-5%**			
V	0.369	0.775				0.106	0.223				0.369	0.775			
T	0.330	0.693				0.095	0.200				0.330	0.694			
V × T	0.738	NS				0.212	NS				0.738	1.551			

Lipid peroxidase

With increased duration of applied waterlogging stress, lipid peroxidase activities of the roots were found to increase (Table 3). Waterlogging condition imposition during the vegetative stage showed highest lipid peroxidase activity in the treatment where 12 days of waterlogging was maintained. Among the genotype Sadiya Local showed the highest lipid peroxidase activity and in the genotype NVL-855 per cent increase over control was found to be highest. An increase in lipid peroxidase activity under waterlogged condition has been reported in mungbean by Sairam *et al*. (2011) and in pigeonpea by Kumutha *et al*. (2009).

Plant height

Significant variation in plant height (Table 4) was observed due to genotypes as well as waterlogging stress. For waterlogging introduced at vegetative stage, the genotype Pratap showed the highest plant height followed by KM 2355 and NVL-855 whereas the genotype AKM 12-28 showed lowest plant height. Under waterlogged condition, the per cent reduction was found to be the lowest for the genotype Sadiya Local. Though plant height is genetically controlled, waterlogging also plays an important role in its regulation. It was suggested that during the waterlogging stress, reduction in plant height was mainly associated with the oxygen deficiency due to the anaerobic condition which affects the normal growth and development of the root system (Wample and Thorton, 1984). Less root activity ultimately results in poor absorption of nutrients and translocation of the photosynthates within the plant, thus reducing the height of the plant. Similar results were reported by Vijayarengan and Dhanavel (2005) and Jaffar Ullah (2006) in greengram.

Leaf area

Wide variability was observed among the genotypes and the different duration of applied waterlogging in terms of leaf area per plant (Table 4). The genotype Pratap showed the highest leaf area followed by KM 2355 and NVL-855. Genotype Sadiya Local showed the lowest leaf area per plant but in this genotype the lowest per cent reduction over control was observed. On an average waterlogging at vegetative stage decreased leaf area by 9.72 per cent. Reduction in green leaf area was mainly associated with the death of the existing leaves in maize (Srivastava *et al*., 2007). Loss of turgor, reduction in average leaf sizes, premature senescence and abscission of older leaves were the major causes of reduced leaf area in pigeonpea under waterlogging condition (Takele and Mcdavid, 1995).

Root length

With increase in the durations of simulated waterlogging condition there was increasing decline in root length (Table 5). In all genotypes shortest root length was found in treatment where 12 days of waterlogging period was maintained. Reduction in root length might be due to depleted oxygen at root zone and energy starvation of the roots. Inhibition of root growth under waterlogging condition was observed in

Table 6: Number of pods plant^{-1}, no. of seeds pod^{-1} and seed yield plant^{-1} measured at harvest.

Genotypes	Number of pods plant^{-1}					Number of seeds pod^{-1}					Seed yield plant^{-1}(g)				
	T1	T2	T3	T4	Mean	T1	T2	T3	T4	Mean	T1	T2	T3	T4	Mean
NVL-855	10.15	9.10	7.98	6.78	8.50	8.10	7.25	6.50	6.15	7.00	2.70	2.35	1.90	1.65	2.15
KM 2355	7.75	7.05	6.05	5.35	6.55	9.46	8.81	8.03	7.25	8.39	2.60	2.00	1.65	1.35	1.90
AKM 12-28	10.55	9.89	8.79	8.42	9.41	9.14	8.67	7.95	7.00	8.19	3.25	2.85	2.30	2.00	2.60
Pratap	12.10	11.30	9.55	9.15	10.52	9.06	8.00	7.50	6.75	7.82	2.95	2.55	2.10	1.75	2.33
Sadiya Local	13.25	12.56	11.25	10.50	11.89	8.72	8.42	7.56	7.10	7.95	2.85	2.55	2.30	2.00	2.42
Mean	10.76	9.98	8.72	8.04		8.89	8.23	7.50	6.85		2.87	2.46	2.05	1.75	
	SE d ±	**CD-5%**				**SE d ±**	**CD-5%**				**SE d ±**	**CD-5%**			
V	0.241	0.507	0.454	1.015		0.098	0.206				0.072	0.150			
T	0.216	0.454				0.088	0.184				0.064	0.135			

maize and this reduction in root growth was attributed to susceptibility of root tips to anaerobic stress (Fausey *et al*., 1985). Reduction in root growth could be due to energy starvation of the root as a consequence of impaired aerobic respiration in gram (Krishnamoorthy *et al*. 1987).

Root volume

A perusal of the data (Table 5) revealed that there were significant variations in the root volume per plant due to genotype as well as waterlogging treatment. The genotype Pratap exhibited highest root volume however per cent reduction in root volume over control was highest in NVL-855 and lowest per cent reduction was recorded in Sadiya Local. Reduction in root volume is probably due to reduction in root length and number of adventitious roots and root branching due to the applied waterlogging stress. Similar, reduction in root biomass under waterlogged condition was observed in gram by Krishnamoorthy *et al*. (1987).

Number of root nodules

Significant variations in the number of root nodules per plant (Table 5) due to genotype as well as waterlogging treatments were observed. Genotype Pratap showed highest number of root nodule whereas KM 2355 showed lowest number of effective root nodules. The reduction in the number of nodules under waterlogged condition could be linked to the inhibitory effects of waterlogging on the nodule formation. Under the waterlogged condition the formation of new root nodules was inhibited and also degradation of the existing root nodules takes place (Minchin and Summerfield, 1976). Similar findings were reported in greengram by Vijayarengen and Dhanavel (2005) and Kumar *et al*. (2013).

Number of pods plant^{-1}

Number of pods plant^{-1} (Table 6) was influenced significantly by genotypes and waterlogging treatments. Pertaining to water logging treatment, per cent reduction in pod number was found to be the lowest in the genotype Sadiya Local whereas in the genotype Pratap the highest per cent reduction was found. Imposition of waterlogging for four, eight and twelve days led to 7.25%; 18.93% and 25.28% reduction in number of pods plant^{-1} respectively. Similar reduction in number of pods plant^{-1} as influenced by waterlogging were reported by Laosuwan *et al*. (1994) and Jaffar Ullah (2006) in greengram.

Number of seeds pod^{-1}

Longer exposure to waterlogging condition resulted in progressively higher reduction in number of seeds pod^{-1} (Table 6). Waterlogging resulted in lowest per cent reduction in this trait in genotype Sadiya Local whereas in case of the genotype Pratap showed the highest per cent reduction of seeds pod^{-1}. Increase in duration of simulated waterlogging condition caused more reduction in the number of seeds pod^{-1} in all the genotypes compared to the next lower length of duration of waterlogging. Imposition of waterlogging for four, eight and twelve days led to 7.47%; 15.60% and 22.99%

Table 7: Harvest index.

Genotypes	Harvest index (%)				
	T1	T2	T3	T4	Mean
NVL-855	31.56	29.45	27.52	25.34	28.47
KM 2355	32.88	28.17	25.73	24.76	27.88
AKM 12-28	34.20	32.38	30.66	28.29	31.38
Pratap	32.24	30.16	28.55	26.27	29.30
Sadiya Local	33.13	31.67	30.87	28.99	31.16
Mean	32.80	30.37	28.66	26.73	
	SE d ±	**CD-5%**			
V	0.628	1.322			
T	0.554	1.165			
V × T	1.240	NS			

reduction in the number of seeds pod^{-1} respectively. Reduction in number of seeds pod^{-1} by exposure to waterlogging were reported in greengram by Jaffar Ullah (2006) and Ara *et al*. (2015).

Seed yield plant^{-1}

Genotype AKM 12-28 exhibited highest seed yield plant^{-1} (Table 6) when waterlogging was imposed followed by Sadiya Local and Pratap. Increase in the durations of waterlogging led to progressive decrease in seed yield plant^{-1}. Highest per cent reduction in seed yield was shown by NVL-855 and lowest reduction was recorded by genotype Sadiya Local over control. Reduction in seed yield in waterlogging condition might be causally related to oxygen deficiency and less root activity. Impairment of water absorbing ability of the plants as caused by anaerobic condition might caused reduction of translocation of photosynthate from the leaves and pod walls to the developing seeds thereby causing reduction in seed yield (Hocking *et al.,* 1987). Genotypic sensitivity to waterlogging could again be related to the level of endogenous plant hormones, which control the dropping of flowers and/or the loss of pod setting. Reduction in seed yield due to incidence of waterlogging were reported in greengram by Laosuwan *et al*. (1994) and Jaffar Ullah (2006).

Harvest index

Waterlogging condition imposed at vegetative stage could influence the harvest index (Table 7) of genotypes significantly. Twelve days of waterlogging stress during the vegetative stage, resulted in the highest per cent reduction in harvest index in genotype KM 2355 and lowest per cent reduction was recorded in Sadiya Local. Harvest index is influenced by both the source and sink capacity. The tolerant genotype under stress situation by virtue of their comparatively better possession of leaf area, chlorophyll content *etc.* use to have higher photosynthetic rate (Prasanna and Ramarao, 2014) leading to more availability of biomass for initiation and completion of flowering, seed development and grain development (sink) *etc.* as compare to the susceptible genotype. In this regard the genotypes Sadiya Local and AKM 12-28 accompanied by genotype Pratap could be considered as better genotype because they could maintain higher root biomass, root length *etc*. even when exposed to longer duration of simulated waterlogging stress, resulting in higher seed yield and harvest indices in these genotypes.

CONCLUSION

The greengram genotypes showed tolerance to different degrees in their growth and development under waterlogged condition. The waterlogged condition found to affect the morphological, physiological, biochemical and yield attributing characters of the crop. With the increase in the duration of waterlogging, the effect was found to be more detrimental.

Based on the results obtained in the present investigation, it can be stated that, germination percentage and vigour index responded negatively to waterlogging stress, also the morphological parameters like plant height, number of leaves and number of pods decreased with the waterlogging treatment. Biochemical parameters like lipid peroxidase and superoxide dismutase activity were found to increase under waterlogging condition whereas on the other hand nitrate reductase activity decreases. All the waterlogging treatments decreased the harvest index and the final yield in all the genotypes. The reduction was found to be the highest under the longest duration of waterlogging imposed. In terms of genotypic variations, the genotype Sadiya Local showed lowest per cent decrease in physiological and yield parameters like leaf area, seed yield, seeds pod^{-1} and harvest index followed by genotype AKM 12-28. The genotype NVL-855 showed highest decrease in these parameters under waterlogged condition. Among the five genotypes studied, Sadiya Local and AKM 12-28 can be considered to be tolerant to waterlogging imposed during early vegetative stage of the crop.

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