The Pharma Innovation Journal 2022; SP-11(5): 1757-1761

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; SP-11(5): 1757-1761

www.thepharmajournal.com
Received: 01-03-2022
Accepted: 05-04-2022

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Assessment of growth and heat susceptibility index of different rice genotypes subjected to heat stress

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Abstract

The present investigation entitled "Assessment of growth and heat susceptibility index of different rice genotypes subjected to heat stress" was carried out at Regional Agricultural Research Station, AAU, Titabar in split-plot design with treatments (control and high temperature stress) as main plot treatments and 33 genotypes as sub-plot treatments. The high temperature treatment was imposed by covering the one set of genotypes with polyethylene sheet to raise the temperature and allowed to grow inside the enclosure from panicle initiation until physiological maturity. Elevated temperature had no significant effect on mean days to flowering and days to maturity for all the genotypes. However, significant differences were observed between varieties. Less reduction in Leaf area index were observed in IET 26775, IET 26776, IET 26778, Gontra Bidhan-3, N22, S-458, 175-2K within the range of 4-10% compared to control. Dry matter heat susceptibility index (DMHSI) varied between a minimum of 6.76 (N22) to a maximum of 41.52 (IET 26777). The grain yield heat susceptibility index (GYHSI) was lowest 11.24 in 175-2K. Amongst the remaining varieties IET 26757, IET 26778, S-458 and N22 performed relatively better with < 15 grain yield heat susceptibility index (GYHSI).

Keywords: Rice, heat susceptibility index, heat stress, leaf area index

1. Introduction

Rice is the most important staple food of more than half of the world's population. In India, several studies have been conducted on cereal crops in response to climate change. The rising atmospheric carbon dioxide and temperature affects food production in many ways across the globe. The rice production and productivity are climatically controlled. Temperature affects at different growth phases of rice plant with varied responses in rate and duration of growth and development (Kim *et al.*, 1996a, b) [4-6]. High temperature stress frequently causes irreversible damage to plant function and development which substantially reduces grain yield. It also reduces grain quality of rice during grain filling stage. Global warming can reduce tropical rice yields due to increased respiration rate, spikelet sterility, shorter growth duration and reduced assimilates (Matsui *et al.*, 2000) [6]. In rice, permanent damage to the reproductive mechanism of the plant reduces grain yield by 10% for every 1 ^{0}C increase in minimum temperature during the growing season and also increasing mean minimum night time temperature have significant negative effect on yield of rice plants (Peng *et al.*, 2004) [7]. Varietal component will continue to play a pivotal role in mitigating the adverse effect of climate change in time to come. Performance of different varieties are assessed based on the grain yield per unit of land. This is an important indicator but with climate change an emerging scarcity of water and energy, other indicators like stability and efficiency are also acquiring importance. The cultivars of the rice plant largely defines the characteristics of each growth phase, although the growth environment of the plant also contributes to the overall source-sink dynamics of the plant.

Identifying rice genotypic variation through field screening for high temperature tolerance is required for initiating breeding programme to develop rice cultivars capable of high yield under projected climate change condition. In view of high temperature tolerance in rice, the investigation was carried out to identify the importance of genetic variability.

2. Materials and Methods

The study was conducted in the Regional Agricultural Research Station, Titabar during the year 2017 in Kharif season. A total of 33 genotypes which were collected from Indian Institute of Rice Research, Hyderabad were included in the study and it was conducted in split plot design with treatments as main plot and genotypes as sub plot.

Two sets of rice genotypes were kept, one for control and the other one for imposing high temperature stress. One month old rice seedlings were transplanted in two blocks or stripes, one for control and another block for imposing heat stress by covering the block with polythene sheet (<92% transmittance), supported by bamboo sticks like a tunnel immediately after panicle initiation stage until maturity. The increase in maximum temperature was 1-3.5 ^{0}C over the ambient temperature and minimum temperature had increased by 0.5-1.5 ^{0}C. Control block was kept uncovered. Each entry was sown in 3 rows of 3m length maintaining 20 cm spacing between rows and plant to plant distance. Each row was treated as a replication and all the observations were recorded for each row separately. A minimum-maximum thermometer was installed inside the tunnel and both minimum and maximum temperatures were recorded everyday inside the tunnel. Similarly a max-min thermometer was kept outside for recording both temperatures everyday outside the tunnel as shown in fig 1.

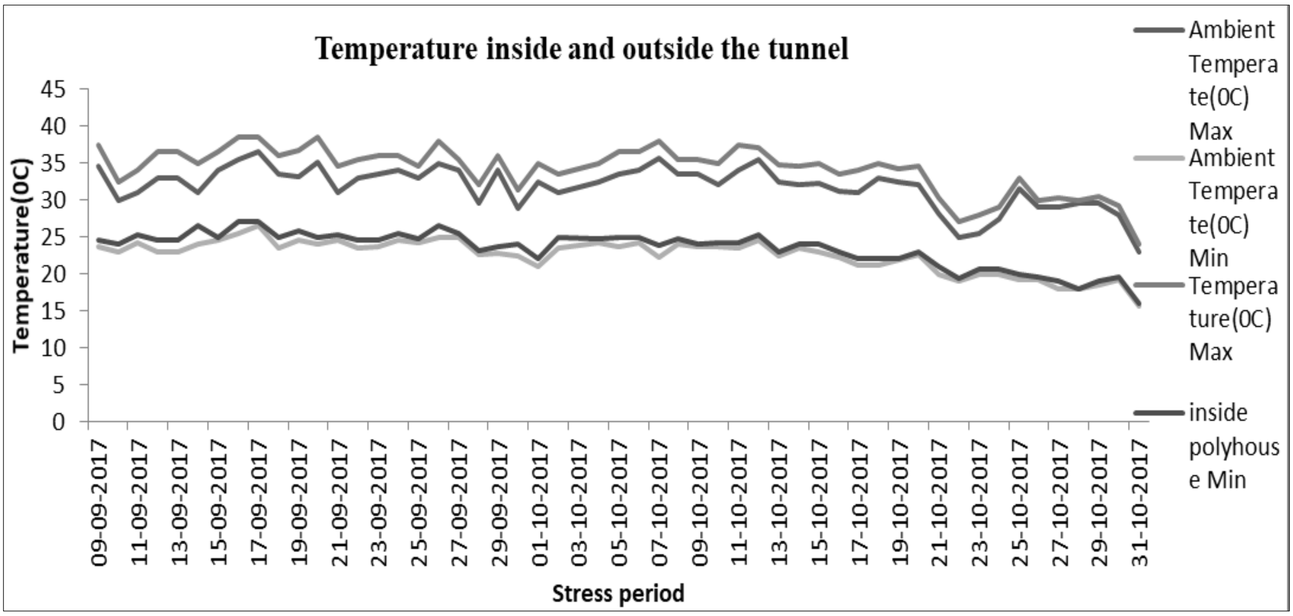

Fig 1: Temperature inside and outside polythene tunnel during reproductive stage of the crop

2.1 Days to flowering: Date at which 50% ear heads was noted for each variety, days to heading was calculated by subtracting date of sowing from date of heading.

2.2 Days to maturity: Date at which 50 to 60% crop matured was noted separately from each variety. Days to maturity was calculated by difference between date of sowing date of maturity. Final reading was taken as mean of three replications.

2.3 Leaf area index (LAI): The leaf area index was calculated by dividing the leaf area per plant by land area occupied by the plant.

LAI= Leaf area/ Ground area

2.4 Dry matter heat susceptibility index (DMHSI): It was calculated by subtracting mean total dry matter under high temperature stress from ambient condition.

2.5 Grain yield heat susceptibility index (GYHSI): It was calculated by subtracting mean grain yield under high temperature stress from ambient condition.

3. Results and Discussion

Days to 50% flowering was not significantly varied between the treatments as shown in Table 1. However, there were significant variation among the varieties in respect of days to 50% flowering. Similar trend was noticed in respect of days to maturity as in case of 50% flowering. The mean days to 50% flowering varied between 75 days (IET 26762, IET 26771 and IET 26774) to maximum 106 days (IET 26773) under elevated temperature. In contrast it was varied between 75 days (IET 26762) to maximum of 107 days (IET 26773) under ambient condition. The mean days to maturity varied between 109 days (IET 26762 and IET 26771) to maximum 140 days (S-458) under high temperature. Whereas, it was varied between 109 days (IET 26762) to maximum141 days (S-458). Prasad *et al*. (2006) [8], reported reduction in number of days to 50% flowering in all rice cultivars under high temperature stress due to inhibition of panicle exertion. High temperature stress caused reduction in the duration of grain-filling phase and considered as unfavourable for the period between flowering and maturity (Tian *et al.*, 2007). Sailaja *et al.* 2015 observed reduction in number of days to physiological maturity in all the rice cultivars under heat stress.

Table 1: Effect of high temperature stress on days to 50% flowering and days to maturity

	Days to 50% flowering and days to maturity			
Genotypes	**Days to 50% flowering**		**Days to maturity**	
	Control	**High temperature**	**Control**	**High temperature**
IET 26755	82	82	117	117
IET 26756	79	79	114	114
IET 26757	82	81	114	113
IET 26758	96	95	131	130
IET 26759	79	79	115	115
IET 26760	82	81	116	115
IET 26761	79	78	113	112
IET 26762	75	75	109	109
IET 26763	96	95	133	132
IET 23354	79	78	112	111
IET 24911	85	85	118	117
IET 24914	85	84	113	112
IET 24904	84	84	115	115
IET 26764	96	95	131	130
IET 26765	85	84	115	114
IET 26766	79	78	112	111
IET 26767	79	79	112	111
IET 26768	94	93	131	130
IET 26771	76	75	110	109
IET 26772	85	84	112	111
IET 26773	107	106	137	136
IET 26774	76	75	112	111
IET 26775	88	87	122	121
IET 26776	82	81	110	110
IET 26777	94	94	127	126
IET 26778	85	84	118	117
IET 26780	79	78	112	111
IET 24705	85	84	112	111
Gontra Bidhan-3	82	81	113	112
IET 24708	82	81	115	114
175-2K	105	105	138	138
S-458	105	104	141	140
N22	95	94	131	130
Mean	86.12	85.39	119.12	118.33
	C.D(0.05)	SEd(±)	C.D(0.05)	SEd(±)
Mainplot		NS	0.10	NS 0.17
Subplot		1.03	0.51	0.53 0.26
Subplot at same level of mainplot		NS	0.73	NS 0.38
Mainplot at same level of subplot		NS	0.73	NS 0.41

Table 2 showed decreased LAI under high temperature stress condition. The mean LAI ranged from 1.93 to 4.40 and 1.4 to 4.1 under control and high temperature stress condition respectively. The percent reduction in stem weight at flowering due to high temperature stress ranged from 4-27.5%. Less reduction were exhibited in IET 26775, IET 26776, IET 26778, Gontra Bidhan-3, N22, S-458 and 175-2K within the range of 4-10% compared to control. Higher reduction (>25%) were observed in IET 26762, IET 26773. Overall, high temperature stress reduced (13.81%) LAI compared to control. High temperature stress strongly reduced photosynthesis rate and stomatal conductance which ultimately caused reduction in leaf area index (Shah and Paulsen, 2003) [10]. There was greater improvement in LAI at optimal average temperature, but decreased at both higher and lower than optimal temperature (Jamieson *et al.*, 1995) [3].

Table 2: Effect of high temperature stress on leaf area index (LAI) at flowering stage

		Leaf area index	
Genotypes	**Control**	**High temperature**	**Per cent reduction**
IET 26755	2.12	1.75	17.45
IET 26756	3.83	3.20	16.38
IET 26757	2.92	2.40	17.81
IET 26758	2.13	1.73	18.75
IET 26759	3.20	2.60	18.83
IET 26760	2.41	2.02	16.29
IET 26761	3.37	2.80	16.84
IET 26762	1.93	1.40	27.46
IET 26763	3.65	3.00	17.88
IET 23354	2.54	2.10	17.32
IET 24911	3.32	2.70	18.60
IET 24914	3.05	2.60	14.75
IET 24904	3.17	2.70	14.83
IET 26764	3.01	2.67	11.31
IET 26765	2.76	2.37	14.04
IET 26766	3.59	3.10	13.65
IET 26767	2.52	2.13	15.58
IET 26768	3.87	3.30	14.79
IET 26771	3.78	3.30	12.63
IET 26772	3.30	2.84	14.03
IET 26773	2.04	1.50	26.47
IET 26774	3.60	3.04	15.40
IET 26775	3.06	2.81	8.36
IET 26776	3.06	2.80	8.41
IET 26777	2.73	2.40	12.20
IET 26778	3.99	3.70	7.34
IET 26780	3.57	3.09	13.36
IET 24705	3.52	3.00	14.85
Gontra Bidhan-3	3.05	2.75	9.93
IET 24708	2.48	2.20	11.40
175-2K	4.39	4.00	8.80
S-458	4.29	4.10	4.42
N22	4.40	4.10	6.82
Mean	3.17	2.73	13.81
		C.D.(0.05)	SEd(±)
Mainplot		0.43	0.09
Subplot		0.57	0.28
Subplot at same level of mainplot		NS	0.40
Mainplot at same level of subplot		NS	0.41

Data presented in fig 2 revealed that dry matter heat susceptibility index was lowest in the genotypes *viz*. 175-2K, N22, S-458 IET 26778 within the range (6-10), whereas highest was observed in IET 26777, IET 26768 within the range (34-41) and grain yield heat susceptibility index was lowest in N22, 175-2K, S-458, IET 26757, IET 26778 within the range (11-14) which indicated relative tolerance towards heat stress as shown in fig 3. The genotypes with high positive heat susceptibility index values are susceptible to higher temperature and vice versa (Fisher and Maurer, 1978) [2]. Heat susceptibility index actually provides a measure of yield stability based on minimization of yield loss under stressed compared to non-stressed conditions rather than on yield level under dry conditions (Clarke *et al*., 1984) [1].

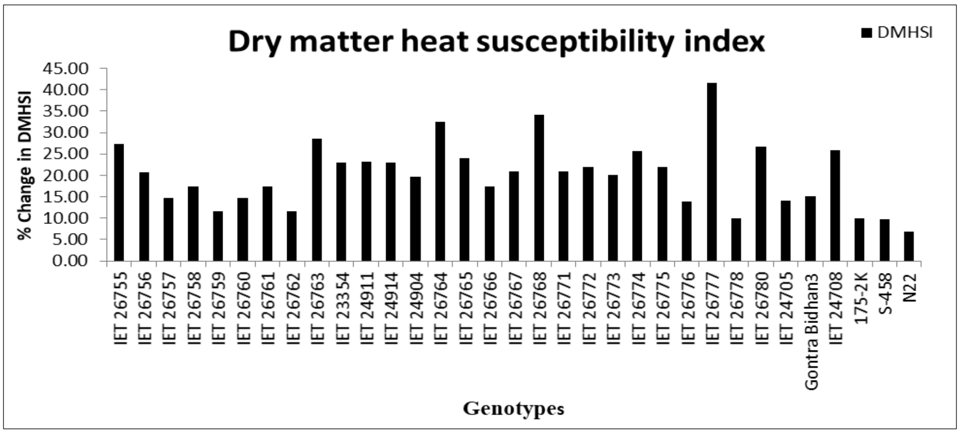

Fig 2: Effect of high temperature stress on dry matter heat susceptibility

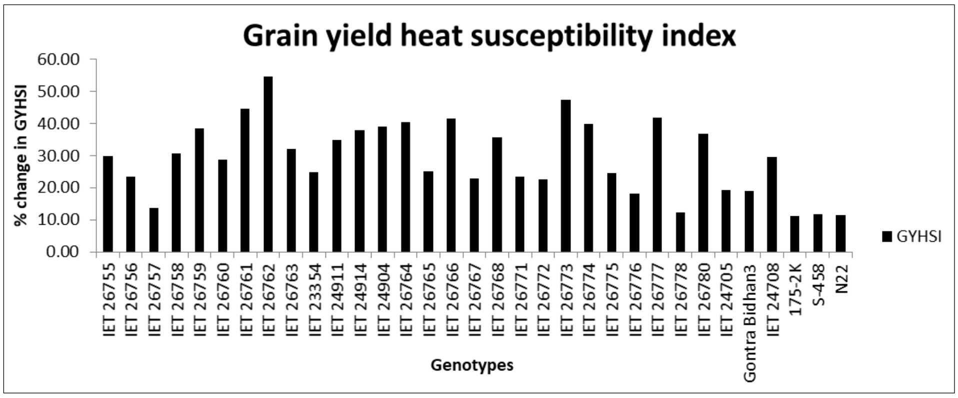

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Fig 3: Effect of high temperature stress on grain yield heat susceptibility

4. Conclusion

The temperature is rising each year with major fluctuations generating enormous challenge for crop production. To deal with such circumstances, only physiologically efficient or resistant genotype is a solution for crop production. Heat Susceptibility Index and different growth parameters were evaluated to select superior genotypes that are tolerant to high temperature stress. Based on this study we can conclude that among the tested varieties 175-2K, S-458 and IET 26778 were found efficient against high temperature stress condition, which has proved to be useful for different breeding programme related to heat stress.

4. Acknowledgement

The author, with immense pleasure, takes the privilege to acknowledge the Regional Agricultural Research station, Assam Agricultural University, Titabar for providing all the facilities to conduct this study. First author gratefully acknowledges guidance provided by Dr. P.C. Dey Principal Scientist, during this study with his valuable and incredible support, encouragement, constructive criticism, liberal help and untiring efforts rendered throughout the tenure of the investigation.

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