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Research Article

COMPARISON AMONG TERMINAL HEAT STRESSED VERY LATE SOWN AND IRRIGATED NORMAL SOWN GENOTYPES ON THE BASIS OF DIFFERENT PHYSIOLOGICAL AND YIELD COMPONENT TRAITS

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Abstract- Different wheat varieties were grown under the normal irrigated and very late planting situations, under wheat improvement project JNKVV, Jabalpur, Madhya Pradesh in order to expose plants to different level of temperature and water regime, since the two situation differ in the total amount of rainfall and number of irrigation supplied during the growing season. Plants were suffered from the terminal heat stress as well as drought stress in the very late sown condition. Since genotype, PBW-343/CDWR-9563-1 showed better performance under both planting situations on basis of grain yield. MP-3349/MP-3222, HD-2864, and GW-366 were the genotypes showed high amount of chlorophyll content, higher relative water content and coolest canopy under both planting situations. All measured parameter, chlorophyll content, relative water content and canopy temperature are good physiological indices of drought and heat stress tolerance and can be used for the enhancement of drought and heat tolerance genotypes in wheat.

Keywords- Wheat, Heat, Chlorophyll content, Relative water content, Canopy temperature.

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Introduction

Globally, wheat is the leading source for human food, having second position after rice in terms of total production tonnages and number one food grain consumed directly by human beings. It is estimated that more than 35 per cent of the world population depends on wheat [1,2]. It continues to retain this pride of place with its roots ramifying into the depths of human culture. Even today, it occupies primary position among all the cereal crops due to its feeding boon to mankind and the most important cereal crop, it is the stable diet for more than one third of the world population and contributes extra calories and protein to the globe than any other cereal [3]. In India, Madhya Pradesh is the third largest producer state of wheat with 18.40 million tonnes from the 56 million hectares area [4]. Wheat cultivation in Madhya Pradesh is characterized by the prevalence of high temperatures during the crop growth period. This is mainly due to the fact that large area of wheat [70 %] is grown under rainfed conditions and only minute division of the growing stages experiences the cool climate. Very often the crop is exposed to terminal heat stress causing potential yield loss. Drought is the another most severe stress that causes significant losses in growth and efficiency of crop [5]. Heat and drought induces significant changes in physiological and biochemical activity of plant. Several plants have a set of physiological traits that allows them adapt tolerance water stress conditions. Adaptations to the decrease in water potential because of drought may vary considerably among species [6]. Response of plant against the water stress include morphological and biochemical changes and later as sever water stress become more dangerous damage functional activity and plant parts [7]. Researchers linked a range of physiological responses against the drought in crop plant with their tolerance mechanisms, such as: high chlorophyll content and relative water content [8]. Drought tolerant wheat species can be characterized response of various growth stages, change in water content of tissues when exposed to low water potential, stomatal conductance, accumulation of ion and variation in the fluorescence stimulation parameters under water stress [9]. A major challenge in conventional breeding for drought and heat tolerance is the identification of reliable screening methods and selection criteria to make possible detection of heat or drought tolerant genotypes. Several screening techniques and selection strategies have been proposed by different researchers. However, to fulfill the task of meeting the increasing demand of wheat and changing circumstances there is an urgent need to breed the high yielding wheat genotypes tolerant to high temperature and low moisture stress suitable under semi irrigation. Physiological mechanisms that enable plants to adapt to water shortage and maintain their growth and productivity during stress period could help in screening and selection of genotypes showing tolerance and using these characters in breeding programs [10]. Relative water content, chlorophyll content and canopy temperature [CT] is a useful indicator of crop water status [11] and has potential for indirect selection of plants tolerant to drought and heat stressed environments [12]. Canopy temperature [CT] has been used as a screening tool for predicting high wheat yield in rain fed environments [13-16]. Since leaf temperature is depressed below air temperature when water evaporates, CT is an indirect measure of the [instantaneous] transpiration at the whole-crop level [17] and plant water status. Genotypic variation has been reported for CT in wheat [18-21]. In addition, yield evaluation in early generation's crop is complicated because yield per plant may not be related to crop yield. Progress through plant breeding by means of physiological traits was achieved by the selection process complement to conventional breeding for yield. [22-25].

Materials and Methods

Eighteen bread wheat genotypes were studied [Table-1]. Seeds were obtained from Wheat Improvement Projects, seed breeding farm JNKVV, Jabalpur and first sown under irrigated normal sown conditions in the field on 22th Nov. 2012 and second sown under very late sown heat stressed condition on 15th Jan. 2013. Crop plants were sown in three replications in randomized complete block design within the plots of four rows each 2.5 m in length and 20 cm apart. Normal agronomic practices were followed and related metrological parameters were obtained from the research station. Chlorophyll content, relative water content [RWC] and canopy temperature were estimated on the first fully expanded leaf [third from top] at the grain filling stage under both the planting situations. The yield and yield attributing trait *viz*., number of effective tillers/plant, grains/ear, test weight and biological yield per plant were studied under both the planting situation. [Table-1]

Table-1 *List of genotypes studied under the both the planting situations.*

S.no	Genotype	S.no	Genotype
1.	JW-3269	10.	401-136/JW-17-1
2.	GW-366	11	PBW-343/CDWR-9563-1
3.	LOK-1	12	MP-3349/MP-3222
4.	JW-3211	13	MP-3342/PBW-343//K-9924
5.	JW-3336	14	PBW-343/CDWR-9563-6
6.	HD-2864	15	MP-3368/MP-4669
7.	HD-2932	16	MP-3359/WH-1092
8.	HI-1544	17	MP-3372/NTAW-1395
9.	MP-3324/MP-3092//MP-322	18	MP-3360/RAJ-4213

Chlorophyll content:- Chlorophyll content was estimated in 4th leaf from the top [fully expended leaflet] with the help of chlorophyll meter [SPAD-502 plus] in normal, late sown and very late sown condition plants. Readings measured in 3 plants per plot at grain filling stages. Chlorophyll content is expressed in terms of SPAD units.

Relative Water Content:- Relative water content was determined by the method described by [26]. 100 mg leaf material was taken and kept in double distilled water in a petridish for two hours to make tissues of leaf turgid. The weights turgid leaf materials were taken after carefully soaking the tissues between the two filter papers. Afterward, this leaf samples was kept in a butter paper bag and dried in oven at 65 0C for 24 hours and dry weights of sample were recorded. The RWC was calculated by using the [Eq-1].

Eq-1

$$\text{RWC [\%]} = \frac{\text{[Fresh weight – Dry weight]}}{\text{[Turgid weight – Dry weight]}} \times 100$$

Canopy temperature: Canopy temperature was recorded by the CTD instrument at grain filling stage by Infra Red Thermometer [Model LT 300 Sixth Sense].

Results and Discussion

Terminal Heat and drought stress are the major abiotic constraints, which verify the yield wheat. Heat stress is the factor, associated with largest economic losses in wheat production [27]. Terminal heat caused by elevated temperatures at the time of wheat spike development is an important restraint to wheat production [28]. During grain filling, elevated temperatures severely decrease the grain-filling period, particularly under late seeding [29]. Wheat genotypes express a differential response to chronic heat as well as a heat shock [30]. Under varying ambient temperatures, plant water status is the most important variable [31]. In general, plants, despite of temperature, tend to maintain stable tissue water status when moisture is sufficient; however, elevated temperatures harshly impair this tendency when water is limiting. Under water-limited conditions, the selection of genotypes having drought tolerance is restricted, based on empirical selection for yields per se and yield by a large genotype and environmental interaction [32]. Mean maximum and minimum temperatures were recorded during all the growing season showed marginal rise in temperature at the end of season or elevated temperature were recorded during grain filling to complete maturity period. [Table-2]. Amount of total rainfall during the early vegetative stages, was not well distributed. Supplemental irrigation was provided with total number of four irrigations at most of the critical stages, indicated that adequate amount of water was provided for quick emergence of seeds. The total amount of the rainfall received during the growing season was comparatively low that is 112.5 mm [Table-3].

Table-2 *Mean maximum and minimum temperature [^{0}C] of growing season*

Meteo. Week	Temperature [^{0}C]		Mean temperature
	Max.	Min.	
25 Nov-1 Dec	27.9	10.6	19.25
2 Dec-8 Dec	28.4	11.5	19.95
9 Dec-15 Dec	28.7	10.6	19.65
16 Dec-22 Dec	29.0	14.0	21.5
23 Dec-29 Dec	25.3	7.1	16.2
30 Dec-31 Dec	23.8	5.0	14.4
1 Jan- 5 Jan	23.3	7.2	15.25
6 Jan-12 Jan	23.0	5.2	14.1
13 Jan- 19 Jan	26.7	10.1	18.4
20 Jan- 26 Jan	21.4	5.0	13.2
27 Jan- 2 Feb	24.6	7.4	16.0
3 Feb -9 Feb	25.9	11.3	18.6
10 Feb -16 Feb	25.2	13.0	19.1
17 Feb -23 Feb	25.0	11.0	18.0
24 Feb -2 Mar	28.0	9.2	18.6
10 Mar-16 Mar	30.7	9.9	20.3
17 Mar-23 Mar	31.6	14.7	23.15
24 Mar-30 Mar	33.4	16.2	24.8
31 Mar-6 Apr	33.8	16.2	25.0
7Apr-13 Apr	35.3	15.2	25.25
14 Apr- 20 Apr	39.5	19.9	29.7

Table-3 *Total amount of rainfall [mm] every month*

MONTH	Rainfall [mm]
DEC	3.2
JAN	2.0
FEB	60.2
MARCH	36.5
APRIL	10.6
Total	**112.5**

Terminal heat stress experienced by the varieties under very late planting condition at the grainfilling stage, however the elevated temperature during this stage leads to imbalance in plant water status leads to severe decrease in yield contributing traits which directly reduces the grain yield of the crop. Impact of heat stress on different were recorded various yield contributing traits *viz*., number of effective tillers/plant, grains/ ear, 1000 grain weight, biological yield per plant. Along with these traits impact of heat stress were also recorded for chlorophyll content, relative water content and canopy temperature.

Chlorophyll content

Presence of high amount of chlorophyll is a desirable trait because it indicates a low degree of photo inhibition of photosynthetic apparatus, therefore reduction in carbohydrate for grain growth [33].Our findings indicate that amount of chlorophyll varies significantly among the varieties and between the two planting situations, however, highest amount of chlorophyll content was reported by the genotype MP-3349/MP-3222, under both the planting situation, normal and very late sown, i.e. 50.6 and 46.9, respectively. whereas lowest amount of chlorophyll content were recorded in genotype MP-3372/NTAW-1395 [39.2 and 22.4] under normal planting and very late planting situation, respectively. These findings are in agreement with [34&35] who reported 20% reduction in leaf chlorophyll content. [Table-4].

Relative water content

RWC of leaf a more important indicator of water level as compared to other water potential parameters under both heat and drought stress conditions. During plant development stress significantly reduced RWC values [36]. Significant differences in RWC was observed between variety was observed under both the planting situation. Under normal planting situation with supplemental irrigation the maximum and minimum RWC was observed in genotypes HD-2864 [86.1] and MP-3342/PBW-343//K-9924 [58.9]. Very late planting situation differ significantly from normal planting situation, however maximum and minimum value of RWC was recorded in genotypes LOK-1 [68.6] and HD-2864 [58.2]. Deviation observed in RWC may be credited to differences in the capacity of the genotypes to soak up maximum water from the soil and or the ability of plant cells to control water loss through the stomata openings. This phenomenon may be also due to differential ability genotypes to maintain tissue turgor, by osmotic adjustment and consequently the physiological activities. [Table-4].

Canopy temperature

Plants with a strong radicular system are able to satisfy the high evaporative requirements through increase in rates of transpiration under hot irrigated conditions and thus maintain cooler canopies [37]. While studies showed that high temperatures generally decreased photosynthetic rate, considered heat-tolerant, [38] and a faster depletion of soil water [%]. The current experiment identifies the group of coolest genotypes had lower canopy temperature. These results showed that under heat stress, genotypes exhibited cooler canopy under normal planting situation was GW-366 [24 oC] and while highest canopy noticed in MP-3368/MP-4669 [25.5 oC]. The canopy temperature varied from 28.9 oC [GW-366] to 31.7 oC [MP-3342/PBW-343//K-9924] under very late planting situation. Canopy temperature showed significant differences among the genotypes of normal and very late planting situation. Cooler canopy temperatures were associated with genetic gain in yield, in biological yield per plant. [Table-4]

Table-4 *Effect of heat and drought stress imposed by planting wheat varieties in normal [N] and very late planting [VL] situation Chlorophyll content, relative water content [%] and canopy temperature [^{0}C] on wheat genotypes at grain filling stage*

S. no	Genotypes	RWC of flag leaf [%]		Chlorophyll content		Canopy temperature [^{0}C]	
		N	VL	N	VL	N	VL
1	JW-3269	74.9	52.3	44.7	40.2	24.9	30.1
2	GW-366	68.8	52.7	48.9	40.8	24.0	28.9
3	LOK-1	68.6	49.2	47.2	35.4	25.0	31.0
4	JW-3211	71.1	56.7	43.9	33.3	24.5	30.3
5	JW-3336	79.2	48.1	44.0	37.5	25.2	31.0
6	HD-2864	86.1	58.2	43.1	40.1	25.3	30.5
7	HD-2932	78.3	47.8	41.9	36.0	25.1	31.1
8	HI-1544	78.9	58.1	46.0	43.1	25.2	31.2
9	MP-3324/MP-3092//MP-322	77.6	54.5	41.7	41.4	24.6	29.5
10	401-136/JW-17-1	79.7	48.1	43.2	34.5	25.4	30.2
11	PBW-343/CDWR-9563-1	74.7	47.9	42.9	34.3	24.4	29.5
12	MP-3349/MP-3222	75.5	48.9	50.6	46.9	25.0	31.4
13	MP-3342/PBW-343//K-9924	79.1	58.9	44.8	41.1	25.4	31.7
14	PBW-343/CDWR-9563-6	82.1	54.3	44.9	37.5	25.1	31.1
15	MP-3368/MP-4669	69.3	51.3	43.1	40.6	25.5	31.3
16	MP-3359/WH-1092	69.8	55.6	46.4	46.5	24.6	29.5
17	MP-3372/NTAW-1395	75.3	57.1	39.2	22.4	25.1	30.3
18	MP-3360/RAJ-4213	82.7	50.9	42.5	34.1	25.0	30.1

Yield components

The stress factors especially heat negatively affects plant growth and development and leads a sharp reduction in plant productivity [39]. Yield and yield attributing traits of twelve spring wheat varieties were significantly decreased when they received minimum annual precipitation and elevated temperature at the end of season under late planting situation as compared to productivity of genotypes under normal planting situation [40]. The effect of drought stress on wheat grain yield may be analyzed in terms of yield traits, some of which can presume more significance than others, depending upon the stress intensity and developmental growth stage [41]. Yield and yield component decreased significantly as variety experienced stress in the very late planting situation. Number of grains per ear decreased up to approximately 50% as in MP3360/RAJ-4213 under very late planting situation, while the minimum reduction in number of grains per ear from normal to very late planting situation were observed in genotype MP-3342/PBW-343//K-9924 and HD-2864. 1000 grain weight also decreased under very late planting situation and the influence of growing stress were more as observed under normal season. Lowest reduction in 1000 grain weight was reported in genotype MP-3342/PBW343//K-9924 [Table-5]. Present experiment showed that number of grains/main spike, 1000-grain weight, number of effective tillers/plant, biological yield/plant and grain yield/plant were decreased under stressed environment which is also reported by [42]. Number of effective tillers per plant also affected by the stressed environment and significant reduction in all genotypes was observed in the in very late sown situation and highest tiller number effective tillers per plant recorded in JW-3269 and JW-3211 in the normal sown condition and in MP-3324/MP-3092//MP-322 and MP3360/RAJ-4213 in the very late sown condition. Grain yield in all varieties also significantly reduced in the very late sown condition. This reduction in productivity is brought about by a delay or prevention of crop organization, deterioration or demolition of established crops, predilection of crops to insects and diseases, alteration of physiological and biochemical metabolism in plants [43]. However, lowest reduction in grain yield recorded in MP-3324/MP 3092//MP-322 and JW-3336. Significant differences in total biomass between all genotypes were observed and great reduction was observed in the very late planting situation. Lowest reduction in biomass value recorded in LOK-1 and JW-3211

Conclusions

Heat stress, alone or in combination with drought, is a common constraint during grain filling stages for production of wheat in most of the regions. Heat tolerance may possess additive or opposite effects on drought stress. Growth and photosynthesis are two of the most important mechanisms abolished, up to some extent or completely, by heat stress, and both of them are major cause of decreased crop yield. The present study showed that the lower canopy temperature under different availability water conditions caused higher grain yield. The best option for crop production, yield improvement, and yield stability under heat stressed conditions is to develop heat tolerant crop varieties. A physiological approach would be the most striking way to develop novel varieties speedily [44]. Therefore, chlorophyll content, relative water content and canopy temperature has been used as a selected criterion for tolerance in drought and high temperature stresses. Looking overall results, it is clear that these parameters could explain some of the mechanisms, which indicate tolerance to heat; however, their relevance in describing the varietals variability is significant.

Conflict of Interest: None declared

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Table-5 *Comparison among the different traits in wheat genotypes under irrigated normal planting [N] situation and stressed very late planting situation [VL]*

S. NO	VARIETY	Effective tillers plant^{-1}	Effective tillers plant^{-1}	Grains ear^{-1}	Grains ear^{-1}	1000 grain weight [g]	1000 grain weight [g]	Biological yield plant^{-1} [g]	Biological yield plant^{-1} [g]	Yield plant^{-1} [g]	Yield plant^{-1} [g]
		N	VL	N	VL	N	VL	N	VL	N	VL
1	JW-3269	5.33	3.63	60.46	48.60	42.06	37.25	38.30	24.53	14.00	8.85
2	GW-366	4.39	3.20	46.23	27.97	41.13	36.41	34.91	25.76	13.35	9.50
3	LOK-1	4.07	3.37	39.52	27.20	39.18	31.96	39.02	37.40	11.03	8.18
4	JW-3211	5.25	3.93	49.57	37.93	37.44	27.60	38.42	35.60	11.26	8.89
5	JW-3336	5.19	4.33	39.33	23.60	40.86	36.38	32.19	20.36	10.56	8.64
6	HD-2864	4.19	4.02	41.86	33.63	41.28	30.21	32.33	19.48	11.64	8.61
7	HD-2932	4.66	3.20	49.40	37.47	44.21	35.94	31.20	18.40	11.15	7.94
8	HI-1544	4.48	4.07	45.51	31.03	33.74	25.59	32.90	27.91	9.70	6.69
9	MP-3324/MP-3092//MP-322	4.36	4.53	49.40	36.13	41.42	29.04	33.18	27.46	9.73	7.94
10	401-136/JW-17-1	4.06	3.23	50.90	39.73	34.47	25.51	33.86	21.28	11.88	8.35
11	PBW-343/CDWR-9563-1	4.29	3.95	46.40	33.87	35.26	28.76	36.41	26.38	16.16	10.21
12	MP-3349/MP-3222	4.31	1.83	46.85	35.90	38.85	30.94	34.39	24.51	10.63	8.38
13	MP-3342/PBW-343//K-9924	3.99	2.70	46.40	38.40	40.95	40.93	30.79	22.02	9.91	8.10
14	PBW-343/CDWR-9563-6	3.88	3.33	42.50	30.00	39.73	36.71	34.96	21.27	10.33	5.77
15	MP-3368/MP-4669	4.23	2.73	42.13	31.80	34.90	28.10	34.44	24.09	13.07	7.60
16	MP-3359/WH-1092	4.34	3.37	47.46	30.27	40.05	32.42	34.87	22.74	13.44	8.76
17	MP-3372/NTAW-1395	4.93	4.07	47.12	35.63	35.53	29.25	35.78	21.81	14.88	8.55
18	MP-3360/RAJ-4213	4.63	4.43	45.88	34.60	36.10	27.31	30.02	12.86	8.89	4.26