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Canopy Temperature Depression and Stay Green: Major Components for Identifying Terminal Heat Stress Resistant Genotypes of Wheat

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ABSTRACT

Analysis of yielding ability in 20 genotypes of spring wheat (Triticum aestivum) was done on the basis of morpho-physiological parameter including canopy temperature and stay green trait under terminal heat stress. Effect of terminal heat stress was studied by delayed sowing at three different dates viz., normal (S_1; November 26, 2011), late (S_2; December 25, 2011) and very late (S_3; January 10, 2012) taking 20 genotypes of wheat in randomized block design with three replications. Genotypes showed significant differences in their morpho-physiological traits under different environments. At anthesis stage, chlorophyll content in flag leaf decreased in plant of S_2 and S_3 as compare to S_1. Canopy temperature increased with advancement in plant growth as well as with delay in sowing. There was significant reduction in total dry matter production, spike number per unit area, spike lets per spike, grains per spike and 1000 grain weight (test weight) with delay in sowing. On the basis of susceptibility index and relative yield loss, genotypic NW-1014 was found to be the most resistant and genotype K-911 the most susceptible to terminal heat stress. NW-1014 was a poor yielder under normal sown condition (S_1) but yielded highest under S_3, while K-911 yielded highest under S_1 but was poor yielder when sowing was delayed (S_3) among the evaluated genotypes.

Key words: *Chlorophyll content (CC), Canopy temperature (CT), Canopy temperature depression (CTD), Terminal heat stress.*

INTRODUCTION

In India, rice-wheat cropping system is prevalent in the northern part. In this region sowing of wheat is delayed due to late harvesting of rice. In such condition wheat crop faces the problem of terminal heat stress and crop yield is limited due to derangement in physiological processes of plant. It is reported that an increase of 1ºC of mean daily temperature during grain filling stage results in reductions in yield by 570 and 620 kg ha^{-1} in spring and winter wheat cultivars, respectively[23]. Adverse effect of increased air temperature are reported on morphological[13] and physiological[24] traits of plants.

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Physiological traitsincluding e.g., maintenance of leaf chlorophyll content for longer duration (stay green characters), lesser reduction in photosynthetic rate, lower canopy temperature, higher leaf conductance are associated with higher terminal heat tolerance in wheat[6]. In wheat genotypes canopy temperature (CT) is a significant parameter to indicate relative tolerance to terminal heat stress and canopy temperature depression (CTD) is observed to be strongly correlated with yield and yield attributes under such stress[16,4]. Heat stress after anthesis reduces grain weight, quality and total yield by affecting source sink relationship, reducing starch synthesis and limiting movement of photoassimilates to sink or grain[5]. Stay green trait is the important physiological characteristic in which plants show the ability to maintain more photosynthetically active pigments, delayed senescence and thus, facilitate for better growth and yield in plants under drought and heat stress[1,19]. Determination of canopy temperature depression and stay green traits can increase the efficiency of selecting wheat lines for breeding programme and genetic improvement of crop for terminal heat stress prone regions[4,14,15]. Stay green trait is associated with higher yield and terminal heat stress resistance in wheat[9]. Selection on the basis of stay green trait is significant in breeding for terminal heat resistance in wheat[10]. Higher chlorophyll content is directly correlated to stay green trait and it is determined by genetic information of plant that shows high genetic variability[22]. Active photosynthetic process governed by green leaves at the grain filing duration is essential for higher grain yield[2]. Decrease in photosynthetic rate under high temperature stress is correlated with chlorophyll loss or early senescence[3]. It is also proposed that terminal heat tolerant and susceptible genotypes can be indentified on the basis of their susceptibility index[7].

MATERIAL AND METHODS

Twenty genotypes of wheat *viz*. K910-4, K612, K910-30, K307, SVPW-1, K512, K607, K911, HUW648, NW-1014, AAI-11, AAI-12, HUW-658, HD-2733, AAI-13, AAI-16, NW-1035, NW-4081, NW-6007 and K-9162 were selected from the "Heat Nursery" of the Department of Genetics and Plant Breeding, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi and sown in randomized block design (2 m × 1.5 m) with three replications. Sowing was done at three different dates for induction of heat stress i.e., November 25, 2011 (normal sowing), December 26, 2011 (late sowing) and January 10, 2012 (very late sowing); henceforth termed as S_1, S_2 and S_3, respectively. Various morpho-physiological characters such as leaf number, days to physiological maturity, chlorophyll content, canopy temperature, canopy temperature depression, grain weight per 30 cm row length (g) were recorded by using random sampling technique. Chlorophyll content was measures by hand held chlorophyll meter "the Minolta SPAD-502" in plant leaves at anthesis and 15 days after anthesis. Measurement of canopy temperature was done by a hand held infrared thermometer-based equipment (Sixth Sense LT-300) by targeting the canopy tissues at an angle of 45º and air temperature was taken by targeting air above 0.5 meter parallel of the particular genotypeon in bright sunny days between 1200 and 1400 hrs at anthesis and 15 days after anthesis. Canopy temperature depression was measured by using following formula:

CTD = Air temperature (Ta) - Canopy temperature (Tc)

Relative yield loss (RYL) was calculated by following formula as given by Fisher and Maurer[7]:

$$RYL = 1 - [Yd/Yi]$$

Where,

YL = Relative yield loss

Yd =Yield under stress condition (S_3)

Yi = Yield under normal condition (S_1)

RESULTS AND DISCUSSION

On perusal of meteorological data, it was observed that reproductive phase of wheat crop experimented gradual increase in ambient temperature as the sowing date was delayed (Table 1). Leaf number per plant was recorded in all the 20 genotype (Fig. 1) at an interval of 7 days starting from 64 days after sowing (DAS) in S_1, 36 DAS in S_2 and 19 DAS in S_3. Data indicated that under normal sown condition (S_1) the maximum leaf number in all the genotype was attained at 64 DAS, and then it gradually declined. In all genotypes under S_1, except in K 910-4, SVPW-1, K-607, AAI-12, HUW-648, and NW-1035, leaves remained green up to 120 DAS. When sowing was done on December 26, 2011, (S_2), the leaf number per plant attained the maximum at about 57 DAS, but leaf senescence occurred at about 105 DAS. When sowing was done on January 10, 2012 (S_3), the maximum leaf number per plant was recorded at about 47 DAS, which gradually decreased and the minimum leaf number was observed at about 82 DAS. Complete senescence of leaves in crops of S_3 sowing was recorded at 82 DAS. Delay in sowing caused reduction in total leaf number per plant and the reduction was severe particularly when sowing was done very late. As sowing was delayed, the duration between attaining maximum leaf number per plant and senescence of all leaves (maturity) reduced significantly. It was observed that when sowing was done at normal date (S_1) crop matured in about 118 days but when it was sown at December 25, and January 10, 2012 crop matured in about 106 and 93days, respectively. Average grain filling durations under different S_1, S_2 and S_3 sowing dates were 38, 29 and 24 days, respectively.

Chlorophyll content (SPAD unit) in flag leaves of different genotypes was recorded at anthesis and 15 days after anthesis (Table 2). At anthesison on an average, as compare to S_1, chlorophyll content in flag leaf of S_2 and S_3 plants decreases marginally. Generally plants of different genotypes under S_2 and S_3 contents relatively lesser amounts of chlorophyll than plants of respective genotype under S_1. Chlorophyll content in flag leaf of same genotype declined after 15 days of anthesis and the magnitude of reduction increased progressively with further delay in sowing. Mean chlorophyll content after 15 days after anthesis was the minimum (27.60 SPAD units) in HUW-658 and the maximum (48.80 SPAD units) in K 910-30.

Canopy temperature (CT) (^{0}C) was recorded at anthesis and 15 days after anthesis (Table 3). On an average it increased with delay in sowing. While at the anthesisAt 15 days after anthesis mean canopy temperatures under S_1, S_2 and S_3 were 24.03, 25.03 and 29.70 ^{0}C, respectively, while at 15 days after anthesis CT at these stages increased to 26.56, 28.26 and 38.43 ^{0}C, respectively. Genotypic differences were evident, as at anthesis stage on an average canopy temperature in different genotype ranged between 27.00 to 32.52 ^{0}C, while at 15 days after anthesis canopy temperature under S_3 in ranged between 35.40 to 42.20 ^{0}C.

Canopy temperature depression (CTD) (^{0}C) was determined and presented in Table 3. Data were recorded at anthesis as well as at 15 days after anthesis stages. On an average CTD narrowed down with delay in sowing of crop as well as with advancement in plant growth stages. On an average the canopy temperature depression at anthesis stage was the maximum (5.86 ^{0}C) in genotype AAI-11 and the minimum (3.04 ^{0}C) in K 910-4, while at 15 days after anthesis CTD was the maximum (3.67 ^{0}C) in HD 2733 and the minimum (1.76 ^{0}C) in AAI-13.

As sowing delayed, grain yield 30 cm^{-1} row length decreased accordingly (Table 2). Genotypic differences were significant for S_3 sowing. Under vey late sowing condition (S_3) the maximum grain yield (35.22 g 30 cm^{-1} row length) was recorded in NW-1035 and the minimum (16.55 g) in K512. When per cent reduction in grain yield under S_3 as compare to S_1 was calculated, it was observed that the values ranged between 35 to 68%, with the minimum (35.79%) in NW-1035 and the maximum (68%) in K-911and AAI-11.

On the basis of yield under S_1 the relative yield loss (RLY) in different genotypes under S_3 was calculated (Table 2). The value ranged between 0.243 (NW-1014) to 0.679 (K-911). On the basis of RYL among the studied genotypes, NW-1014 was most resistant to terminal heat stress (minimum RYL), while K-911, the most susceptible (maximum RYL). NW-1014 was a poor yielder under normal sown condition (S_1) but yielded highest under S_3, while K-911 yielded highest under S_1 but was poor yielder at S_3 among the evaluated genotypes.

It was observed that when sowing was done at three different dates (S_1, S_2 and S_3) crop matured in about 118, 106 and 93 days respectively. Delay in sowing hastened the senescence of leaf and phases of plant development were completed in shorter durations. It is reported that high temperature hastens plant developmental process (Singh *et al.* 2007). When chlorophyll content in flag leaf of mother shoot was estimated, it was observed that at anthesis under S_1, S_2 andS_3 differences were not large, but after 15 days of anthesis values were significantly lower in S_3 as compare to S_2, and in S_2 as compare to S_1. RYL of different genotypes indicated that genotypes NW-1014 was relatively resistant to terminal heat stress as RYL was of lesser magnitude in this genotype (0.137), while genotype K-911, the most susceptible as RYL was the maximum for this genotype among the studied genotypes. Attempt has been made to identify terminal heat stress resistance and susceptible genotype on the basis of susceptibility index[12]. On the basis of relative yield loss, calculated under similar conditions for these genotypes, K911 was found to be most susceptible and NW1014 most stable to terminal heat stress (Table 2). It was evident that genotypic differences were large, and such variations have already been reported by Reynold *et al.*[14,15]; Joshi *et al.*[8] and Pandey and Srivastava[13]. It is documented that increased atmospheric drought reduces stomata opening resulting in reduction in transpiration rate and causes warming of leaves as a consequence canopy temperature (CT) increased and canopy temperature depression (CTD) (air temperature-canopy temperature) narrowed down[21]. In the present study also as the sowing was delayed canopy temperature gradually increased and air temperature to canopy temperature dispersion narrowed down.

When canopy temperature (CT) at anthesis and 15 days after anthesis were correlated (Table 4) with various yield and yield attributes, it was observed that CT at 15 days after anthesis had negative correlation with dry matter accumulation and grain yield 30 cm^{-1} row length. Correlation between 1000 grain weight and canopy temperature at 15 days after anthesis was also negative (r= -0.364) (Table 4). These observations indicated that increase in canopy temperature at post anthesis stage decreases dry matter accumulation and seed size in wheat. Canopy temperature at post anthesis stage (15 days after anthesis) may be taken as criteria for selecting terminal heat resistant wheat genotypes. Genotypes with relatively lesser CT at 15 days after anthesis may perform better under late sown condition. Munjal and Rena [11] have reported that cool canopy during grain filling period in wheat is an important physiological principle for high temperature stress tolerance. Canopy temperature depression (CTD) has been used as efficient selection criteria for screening wheat genotypes for terminal heat stress resistance[17]. Reynolds *et al.*[18] reported that CTD is the most potential assay for heat tolerance of genotypes. Plant growth duration was reduced by delayed in sowing. Significant reduction was observed in grain filling duration. As sowing delayed, crop experienced elevated air temperature during reproductive growth phase. At 15 days after anthesis significant differences were recorded in flag leaf chlorophyll content of crop sown at S_1, S_2 and S_3. The chlorophyll content decreased sharply in S_3 as compared to S_1 and in S_2. Delay in sowing resulted in increased canopy temperature (CT) at anthesis and at 15 days after anthesis. Significant differences were observed in the CT of crops sown at different dates. As the sowing delayed, CT at 15 days after anthesis increased. Increased canopy temperature at post anthesis (15 days after anthesis) stage decreases dry matter accumulation and seed size in wheat.Maintenance of post anthesischlorophyll content was directly related with 1000 grain weight under late sown condition. Delay in sowing resulted in increased canopy temperature (CT) at anthesis and at 15 days after anthesis. Significant differences were observed in the CT of crops sown at different dates. Genotypes with high chlorophyll content and lower canopy temperature at 15 days after anthesis performed better under late sown condition, therefore,

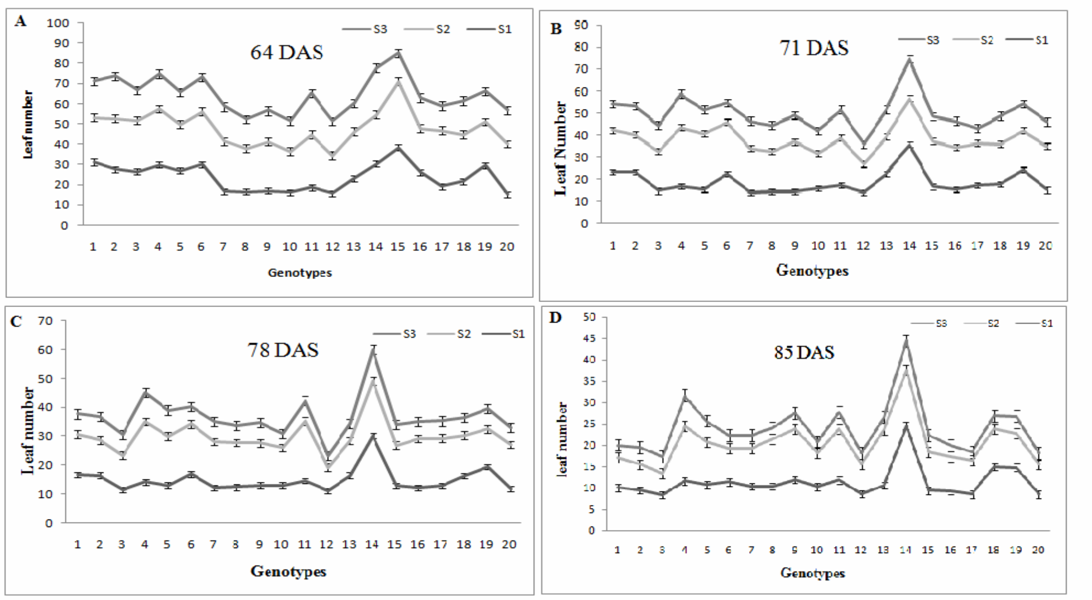

Fig. 1: (A, B,C and D) Variation in leaf number per plant in 20 wheat genotype at an interval of 7 days starting from 64, 71, 78 and 85 days after sowing (DAS) respectively at different dates of sowing (S1 = sowing date November 26, 2011, S2 = December 25, 2011, and S3 = January 10, 2012)

Where (1=K910-4, 2=K612, 3=K910-30, 4=K307, 5=SVPW-1, 6=K512, 7=K607, 8=K911, 9=HUW648, 10=NW-1014, 11=AAI-11, 12=AAI-12, 13=HUW-658, 14=HD-2733, 15=AAI-13, 16=AAI-16, 17= NW-1035, 18=NW-4081, 19=NW-6007 and 20=K-9162aretwenty genotypes of wheat).

Table 1: Weekly meteorological data: Varanasi from November 2011-April 2012

Week no.	Month and date	Rainfall (mm)	Temperature °C			Relative humidity			Sunshine hrs	Evaporation mm
			Max	Min	Difference	Max	Min	Difference		
45	Nov 05-11	0.0	30.3	16.0	14.3	90	34	56	6.9	2.7
46	12-18	0.0	29.6	16.1	13.5	90	41	49	7.4	1.9
47	19-25	0.0	29.9	15.4	14.5	93	43	50	5.9	3.6
48	26-02	0.0	26.1	12.9	13.2	90	41	49	5.9	1.4
49	Dec 03-09	0.0	28.8	14.0	14.8	94	49	45	4.6	1.5
50	10-16	0.0	21.5	10.3	11.2	95	64	31	2.3	1.2
51	17-23	0.0	16.5	7.5	9.0	96	65	31	6.6	1.6
52	24-31	0.0	22.3	7.2	15.1	91	41	50	6.9	2.7
1	Jan 1-7	28.2	20.3	13.0	7.3	92	79	13	3.9	1.7
2	8-14	0.0	18.6	10.6	8.0	89	56	33	3.1	1.8
3	15-21	0.0	22.0	10.6	11.4	86	56	30	6.4	2.8
4	22-28	0.0	21.6	8.3	13.3	86	43	43	7.2	2.9
5	29-04	0.0	22.7	8.5	14.2	88	38	50	8.2	2.5
6	Feb 05-11	0.0	22.7	8.5	14.2	79	48	31	8.5	2.2
7	12-18	0.0	24.3	10.2	14.1	86	51	35	7.8	2.2
8	19-25	0.0	30.3	13.6	16.7	83	41	42	9.7	3.2
9	26-04	0.0	27.8	12.2	15.6	72	32	40	9.8	3.5
10	March 05-11	0.0	29.7	14.5	15.2	74	36	38	8.6	4.0
11	12-18	6.4	28.1	14.5	13.6	75	62	13	7.7	3.8
12	19-25	0.0	33.1	16.2	16.9	68	37	31	9.4	4.5
13	26-01	0.0	36.6	18.1	18.5	59	20	39	9.4	5.5
14	April 02-08	1.3	37.9	21.3	16.6	66	24	42	8.8	4.6
15	09-15	10.3	37.0	21.7	15.3	67	27	40	9.3	5.9
16	16-22	0.0	38.1	22.4	15.7	48	24	24	9.6	8.9
17	23-29	0.0	39.8	23.3	16.5	44	17	27	10.5	7.7

Table 2: Chlorophyll content at anthesis (CC I) and chlorophyll content at 15 days after anthesis (CC II), grain yield (g 30 cm^{-1} row length), susceptibility index (SI) and relative yield loss (RYL) in 20 genotypes of wheat sown at different dates (S_1 = sowing date November26, 2011, S_2 = December 25, 2011, and S_3 = January 10, 2012)

S. No.	Genotype	CC I				CC II				Grain yield (g) 30 cm^{-1}				Relative yield loss
		S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	
1	**K910-4**	46.70	46.70	48.60	47.33	45.53	43.00	44.00	**44.17**	55.77	34.91	23.40	**55.77**	0.580
2	**K612**	46.30	42.00	38.00	42.10	48.00	45.20	46.00	**46.40**	55.03	27.65	25.36	**55.03**	0.539
3	**K910-30**	48.65	46.70	43.95	46.43	46.97	47.70	48.80	**47.82**	46.50	43.26	25.02	**46.50**	0.462
4	**K307**	46.32	42.90	39.00	42.74	46.93	44.00	42.20	**44.37**	56.92	22.23	21.09	**56.92**	0.630
5	**SVPW1**	48.00	46.44	45.00	46.48	47.00	44.00	39.00	**43.33**	48.42	34.13	22.01	**48.42**	0.545
6	**K512**	44.20	44.30	47.00	45.16	49.20	46.93	37.10	**44.41**	35.96	35.07	16.55	**35.96**	0.540
7	**K607**	48.34	48.60	46.80	47.91	45.60	47.00	39.00	**43.86**	53.25	39.88	19.85	**53.25**	0.627
8	**K911**	47.60	40.40	47.00	45.00	42.35	39.87	36.10	**39.44**	65.52	40.93	21.03	**65.52**	0.679**
9	**HUW648**	48.50	47.00	47.50	47.66	46.10	44.60	44.90	**45.20**	55.72	33.49	18.87	**55.72**	0.661
10	**NW1014**	47.40	45.10	49.00	47.16	46.10	44.70	43.00	**44.60**	36.75	38.20	27.82	**36.75**	0.243*
11	**AAI11**	49.50	46.60	39.00	45.03	48.50	49.50	42.83	**46.94**	58.86	44.54	19.14	**58.86**	0.675
12	**AAI12**	47.20	45.90	47.20	46.76	43.70	42.00	37.40	**41.03**	57.38	32.02	22.10	**57.38**	0.615
13	**HUW658**	47.50	49.40	44.26	47.05	42.35	32.00	27.60	**33.98**	58.38	30.53	26.72	**58.38**	0.542
14	**HD2733**	47.40	46.30	48.00	47.23	48.39	43.67	31.40	**41.15**	54.64	27.52	29.86	**54.64**	0.454
15	**AAI13**	48.00	47.00	46.65	47.21	45.53	43.00	39.00	**42.51**	55.89	31.57	20.58	**55.89**	0.632
16	**AAI16**	41.20	41.20	43.40	41.93	43.00	40.57	36.53	**40.03**	50.64	38.19	24.35	**50.64**	0.519
17	**NW1035**	47.10	46.60	37.00	43.56	40.10	47.00	41.40	**42.83**	54.85	35.38	35.22	**54.85**	0.358
18	**NW4081**	47.80	46.50	48.00	47.43	43.50	46.00	41.00	**43.50**	54.38	27.97	19.08	**54.38**	0.649
19	**NW6007**	45.30	44.40	47.00	45.56	48.00	44.00	42.00	**44.66**	50.18	32.00	17.42	**50.18**	0.653
20	**K9162**	48.00	46.34	44.00	46.11	42.47	44.90	46.00	**44.45**	43.658	31.23	21.47	**43.658**	0.508
	MEAN	**47.05**	**45.51**	**44.81**		**45.46**	**43.98**	**40.26**		**52.43**	**34.03**	**22.84**		**0.556**
ANOVA		**SEm±**		**CD 5%**		**SEm±**		**CD 5%**		**SEm±**		**CD 5%**		
Sowing date (S)		0.14		0.28		0.63		1.25		1.69		3.37		
Genotype (G)		0.37		0.73		1.63		3.25		4.36		8.7		
S x G		0.67		1.34		2.82		5.63		7.56		15.07		

*Most resistant to terminal heatstress, ** Most susceptible to terminal heat stress

Table 3: Canopy temperature at anthesis (CT I) and 15 days after anthesis(CT II),canopy temperature depression at anthesis (CTD1) and 15 days after anthesis (CTD II) in 20 genotypes of wheat sown at different dates (S_1 = sowing date November 26, 2011, S_2 = December 25, 2011, and S_3 = January 10, 2012)

S. No.	Genotype	CT I				CT II				CTD I				CTD II			
		S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
1	**K910-4**	24.22	26.22	32.52	**27.65**	26.65	29.32	35.40	**30.45**	4.98	3.48	0.68	**3.04**	2.95	2.28	2.40	**2.54**
2	**K612**	23.44	26.22	32.22	**27.29**	26.22	29.33	37.70	**31.08**	5.76	3.48	0.98	**3.40**	3.38	2.27	3.80	**3.15**
3	**K910-30**	23.66	25.33	31.22	**26.73**	28.22	28.22	37.00	**31.14**	5.54	4.37	1.98	**3.96**	3.60	3.38	0.80	**2.59**
4	**K307**	24.33	25.22	26.22	**25.25**	27.00	28.65	36.70	**30.78**	4.87	4.48	6.98	**5.44**	2.60	2.95	1.10	**2.21**
5	**SVPW1**	23.41	25.22	28.43	**25.68**	26.43	26.43	38.00	**30.28**	5.79	4.48	4.77	**5.01**	3.17	5.17	0.60	**2.98**
6	**K512**	25.22	26.00	28.00	**26.40**	26.33	28.00	41.30	**31.87**	3.98	3.70	5.20	**4.29**	3.27	1.00	2.80	**2.35**
7	**K607**	25.52	25.51	28.66	**26.56**	26.00	28.22	37.50	**30.57**	3.68	4.19	4.54	**4.13**	3.60	3.38	0.30	**2.42**
8	**K911**	25.81	26.22	28.41	**26.81**	29.43	26.34	39.60	**31.79**	3.39	3.48	4.79	**3.88**	2.60	5.26	1.80	**3.22**
9	**HUW648**	23.91	25.33	31.42	**26.88**	26.33	28.00	42.20	**32.17**	5.29	4.37	1.78	**3.81**	3.27	3.60	1.80	**2.89**
10	**NW1014**	24.66	25.33	28.00	**25.99**	26.22	29.95	36.20	**30.79**	4.54	4.37	5.20	**4.70**	3.38	1.65	1.60	**2.21**
11	**AAI11**	23.51	24.00	27.00	**24.83**	26.00	30.00	41.00	**32.33**	5.69	5.70	6.20	**5.86**	5.10	0.40	2.80	**2.70**
12	**AAI12**	23.41	27.22	31.33	**27.32**	26.33	28.41	38.30	**31.01**	5.79	2.48	1.87	**3.38**	3.27	3.19	0.80	**2.42**
13	**HUW658**	23.73	24.00	32.40	**26.71**	26.00	28.00	40.60	**31.53**	5.47	5.70	0.80	**3.99**	3.60	3.60	0.80	**2.66**
14	**HD2733**	22.33	24.42	38.00	**28.25**	25.65	26.33	38.00	**29.99**	6.87	5.28	1.20	**4.45**	3.95	5.27	1.80	**3.67**
15	**AAI13**	23.66	24.00	27.42	**25.02**	27.20	30.00	36.50	**31.23**	5.54	5.70	5.78	**5.67**	2.40	1.60	1.30	**1.76**
16	**AAI16**	23.72	25.00	28.00	**25.57**	25.00	26.00	39.00	**30.00**	5.48	4.70	5.20	**5.12**	4.60	5.60	0.80	**3.66**
17	**NW1035**	23.52	25.22	28.50	**25.74**	26.33	29.66	38.80	**31.59**	5.68	4.48	4.70	**4.95**	3.27	1.94	0.40	**1.87**
18	**NW4081**	23.52	24.50	28.00	**25.34**	27.66	28.00	37.00	**30.88**	5.68	5.20	5.20	**5.36**	1.94	3.60	0.80	**2.11**
19	**NW6007**	24.33	25.33	30.40	**26.68**	26.22	28.00	38.50	**30.90**	4.87	4.37	2.80	**4.01**	3.38	1.80	1.40	**2.19**
20	**K9162**	24.81	27.00	28.22	**26.67**	26.00	29.00	39.40	**31.46**	4.39	2.70	4.98	**4.02**	3.60	0.90	2.00	**2.16**
	MEAN	**24.03**	**25.36**	**29.70**		**26.56**	**28.29**	**38.43**		**5.16**	**4.33**	**3.78**		**3.34**	**2.94**	**1.49**	
ANOVA		**SEm±**		**CD 5%**		**SEm±**		**CD 5%**		**SEm±**		**CD 5%**		**SEm±**		**CD 5%**	
Sowing date (S)		1.24		2.48		1.28		2.56		0.06		0.12		0.09		0.19	
Genotype (G)		3.21		6.40		3.32		6.61		0.16		0.32		0.24		0.49	
S x G		5.57		11.09		5.75		11.45		0.28		0.56		0.43		0.86	

Table 4: Correlation coefficients of all the characters under study as obtained under S_3

	Grain yield 30 cm^{-1}	Harvest index	Spike length	Spikes 30 cm^{-1}	Grains $spike^{-1}$	Grain weight $spike^{-1}$	1000 grain weight	Spikelets $spike^{-1}$	CC I	CC II	CT I	CT II	CTD I	CTDII
Dry weight 30 cm^{-1}	0.887	0.237	-0.044	0.681	-0.105	0.019	0.139	0.209	-0.450	-0.002	0.285	-0.376	-0.210	-0.008
Grain yield 30 cm^{-1}		0.654	-0.141	0.630	-0.182	0.081	0.230	0.009	-0.329	-0.156	0.376	-0.237	-0.269	-0.204
Harvest index			-0.256	0.187	-0.224	0.169	0.322	-0.306	0.012	-0.245	0.324	0.070	-0.231	-0.390
Spike length				0.042	0.635	0.315	-0.147	0.331	-0.479	0.100	-0.276	0.384	0.146	-0.072
Spikes 30 cm^{-1}					-0.123	-0.342	-0.333	-0.231	-0.368	-0.301	0.362	-0.097	-0.119	0.037
Grains $spike^{-1}$						0.401	-0.192	0.192	-0.264	-0.771	-0.255	0.257	0.152	0.054
Grain weight $spike^{-1}$							0.772	0.082	-0.085	0.281	-0.140	-0.112	-0.104	-0.023
1000 grain weight								0.011	0.009	0.450	-0.068	-0.364	-0.115	0.001
Spikelets $spike^{-1}$									-0.314	0.398	-0.153	-0.167	0.007	-0.061
CC I										-0.238	0.259	-0.137	-0.218	-0.132
CC II											-0.271	-0.245	0.095	0.271
CTI												-0.020	-0.885	0.169
CTII													-0.009	0.207
CTDI														-0.176
CTDII														1.000

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