

PHYSIO-AGRONOMIC TRAITS EVALUATION OF WHEAT GENOTYPES FOR ADAPTABILITY UNDER RAINFED CONDITIONS

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ABSTRACT

High temperature stress during grain filling stages is one of the main wheat yield limiting factors under rainfed conditions of Pakistan. A field experiment was carried out to evaluate physio-agronomic traits of different wheat genotypes for better yield and heat tolerance under rainfed conditions. Variable growing conditions during grain filling period were created by sowing crop on normal (November 15) and late sowing dates (December 15). Crop planted on normal sowing date had significant affect ($p < 0.05$) and produced 29% higher grain yield as compared to late planting. Significant variation ($p < 0.05$) was also noticed among genotypes in terms of physiological and agronomic traits under both normal and late sowing dates, as advance line NR-397 and NARC-09 produced significantly higher ($p < 0.05$) grain yields as compared to NR-400 and NR-379. Higher grain yields of these two cultivars were associated with their more number of days to maturity, higher spikes m^{-2} and heavier grains as compared to other two genotypes. At the same time, grain yields of wheat genotypes showed a strong correlation to their leaf chlorophyll (+0.98) and canopy temperature (-0.99) measurements. Higher grain yields of NR-397 and NARC-09 were directly correlated to their better leaf chlorophyll retention and maintenance of low canopy temperature during grain filling periods.

Key words: Wheat, temperature stress, canopy temperature, leaf chlorophyll, genotype's evaluation, rainfed conditions

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INTRODUCTION

Wheat under rainfed condition is cultivated on an area of about 1.5 million hectare annually in Pakistan where average farmer yield is about 1500 kg ha^{-1} . Lower farmer yield is generally attributed to high temperature stress at reproductive growth stages of the crop (Khan *et al.*, 2007; Subhan *et al.*, 2004).

Late planting adversely affect wheat grain yield (Mehboob *et al.*, 2005; Khan *et al.*, 2007) which might be linked to grain mortality due to high temperature injury at reproductive growth stages (Calderini *et al.*, 1999; Wardlaw, 2002). Terminal heat stress shortens grain filling period, disrupt synthesis of starch in the endosperms of the kernels and induce early maturity which cause shrinking of kernels and ultimately low grain weight (Nageswara *et al.*, 2001; Rawson, 1987).

However, significant variations exist among wheat cultivars in terms of grain yield reduction under late planting conditions (Okuyama *et al.*, 2005; Mehboob *et al.*, 2005; Khan *et al.*, 2007). The ability of the wheat genotypes to withstand high temperature stress is associated with better leaf chlorophyll and low canopy temperature maintenance (Renolds *et al.* 1994; Lopes and Reynolds, 2010).

High temperature stress tolerant genotypes can play important role to enhance wheat productivity under rainfed conditions. Study was carried to evaluate candidate wheat lines for their potential to tolerate high temperature under rainfed conditions. Cultivars were planted under normal and late planting dates to create variable climatic conditions as late planted crop is more exposed high temperature during reproductive growth stages.

MATERIALS AND METHODS

A field trial was conducted at field research area of wheat programme, NARC, Islamabad during 2010-2011, situated at coordinates of latitude 33° 42' N and longitude 73° 10' E.. Three advance lines (NR- 379, 397 and 400) and one released variety (NARC-09) of wheat improvement program of NARC, Islamabad were included in the study. The experiment was laid out in RCBD with three replications in split plot arrangement where two planting dates were placed in main plots and four cultivars were assigned to sub-plots.

Seedbed was prepared using disc plow (primary tillage) followed by two cultivators and planking (secondary tillage). Crop was planted at two planting dates, November 15, 2010 (normal) and December 14, 2010 (late) and both sowing dates were harvested on May 06, 2011. The trial was sown in 6-row plots, 5 m long, with a 25 cm row spacing at seed rate of 120 kg ha⁻¹ with self propelled wheat planter. NP fertilizer was applied in ratio of 120: 85, respectively in form of Urea and DAP. Full dose of N and P fertilizers were applied at planting which is regular practice under rainfed conditions. Herbicide i.e. Buctril M (for broad leaf weeds) and Puma Super (for narrow leaf weeds) were used to control weeds in the research area.

Days to physiological maturity were measured when 50% of the spikes showed complete absence of green color. Spike sterility (%) in the field was observed visually as gaping glumes and transparent florets and calculated as average percentage of randomly selected 15 spikes per plot. Grain yield was measured after harvesting, threshing and weighing of grains of 2m² sample area which is then converted into kg ha⁻¹. Samples for 1000 grain weight were taken from the grain yield of each plot. Prior to harvest exact number of spike-bearing culms m⁻² were counted from the sample area. SPAD values of 15 flag leaves per plot were measured for successive three weeks after anthesis by using chlorophyll meter (model SPAD 502). The instrument has been used successfully to screen germplasm for drought and heat tolerance (Reynold *et al.*, 1998). A hand-held Infrared Thermometer (Model AG- 42, Telatemp Crop, Fullerton, CA.) were used to measure canopy temperature. Measurements were taken at 100% canopy cover by holding the thermometer at an appropriate angle (30° from the horizontal and approximately 50 cm above the canopy) and 1 m distance from the edge of the plot to avoid the effect of soil temperature. One measurement per plot was taken between 11:00 and 14:00 hours under calm air conditions (Reynold *et al.*, 1998).

Daily mean, minimum and maximum temperatures at the experimental site were recorded along with relative humidity (RH) and have been provided in Table 1.

Table 1. Mean monthly minimum and maximum temperature, relative humidity and solar radiation at the experimental site growing season 2010-11

Month	Mean temperature (°C)			RH (%)	Radiations (MJm ⁻² d ⁻¹)
	Daily	Max.	Min.		
November	18.1	26.2	9.9	56	14.35
December	11.7	20.3	3.4	57	9.72
January	9.8	16.8	2.8	65	10.08
February	12.4	17.9	6.8	68	8.73
March	19.2	26.5	11.9	57	17.30
April	22.6	29.6	15.5	42	18.99

The data were tested for analysis of variance using Statistix v. 7.0 (Analytical Software, 2000) package. Treatment means were compared using Tukey HSD test at P = 0.05. Correlations between average grain yield and leaf chlorophyll (SPAD value) and canopy temperature (°C) were also determined by using same software (Statistix v. 7.0).

RESULTS AND DISCUSSIONS

Mean canopy Temperature (°C)

Planting dates and genotypes showed significant variation in terms of canopy temperature. Genotypes showed significantly low (p<0.05) mean canopy temperature (23.9 °C) under normal sowing as compared to late planting (25.8 °C; Table 2). Significant variation (p<0.05) among genotypes were also observed as NR-397 and NARC-09 showed significantly low (p<0.05) mean canopy temperatures (23.6 and 23.8 °C, respectively) than NR-379 (25.9 °C) and NR-400 (26.1 °C; Table 2). Interactive studies of sowing date and genotypes also revealed significant variation (p<0.05). Genotypes NR-397 and NARC-09 showed significantly lower (p<0.05) mean canopy temperature under both normal and late planting conditions (Table 2). The variable canopy temperature readings among four wheat cultivars in both the growing conditions might be due to genetic differences of the cultivars which is also mentioned by Reynolds *et al.* (1994) that genotypic variations existed for canopy temperature among the wheat germ plasms under heat stress condition

Results showed negative correlation (-0.99) between canopy temperature and average grain yield. Genotypes with low average canopy temperatures at grain filling stages produced higher grain yields (Fig 1). Canopy temperature has been shown to be well correlated to grain yields of wheat genotypes under heat and drought stressed environments (Reynolds *et al.*, 1994). Low canopy temperatures of random wheat lines were associated with higher grain yields in hot environments (Lopes and Reynolds, 2010). Maintenance of low canopy temperatures of better performing genotypes (NR-397 and NARC-09) under stressful rainfed conditions may be linked to their ability to

extract water through better root system (Lopes and Reynolds, 2010) and with larger stomatal conductance (Reynolds *et al.*, 2005).

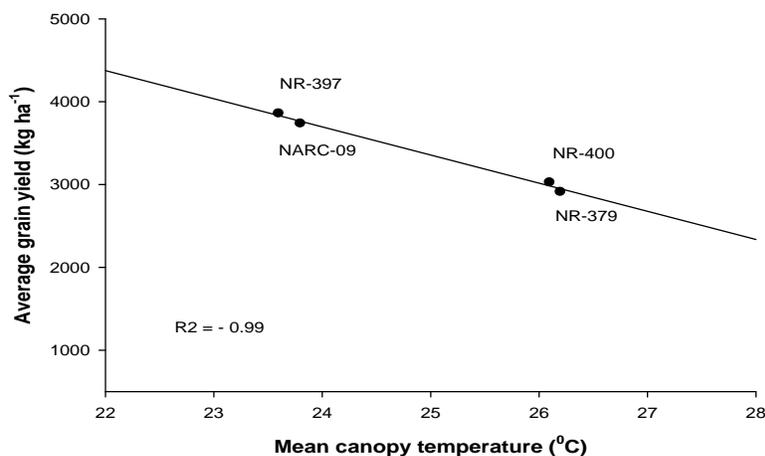


Fig. 1. Correlation between mean canopy temperature and average grain yield of wheat genotypes

Table 2. Effect of normal and late growing conditions on different yield contributing parameters of wheat genotypes

Treatments	Grain yield (kg ha ⁻¹)	DTM (No.)	Spikes m ⁻² (No.)	1000 GW (gm)	Spike sterility (%)	Mean LC (SPAD)	Mean CT (°C)	
Sowing dates								
Normal	3714 a	164 a	409 a	39 a	14 a	48.9 a	23.9 b	
Late	2640 b	133 b	203 b	33 b	30 b	43.9 b	25.8 a	
Genotypes								
NR-400	3025 b	147 b	303 ab	38 a	26 a	45.2 c	26.1 a	
NR-397	3395 a	152 a	316 a	39 a	21 b	48.5 a	23.6 c	
NR-379	2910 b	147 b	287 b	35 b	24 a	45.0 c	25.9 a	
NARC-09	3377 a	153 a	319 a	34 b	19 b	47.0 b	23.8 b	
Sowing date x Genotype								
Normal	NR-400	3550 b	162 a	407 ab	37 b	16 c	48.2 bc	24.7 c
	NR-397	3950 a	165 a	417 a	42 a	14 c	50.5 a	22.7 d
	NR-379	3480 b	164 a	385 b	36 b	15 c	47.6 c	25.3 a
	NARC-09	3875 a	165 a	428 a	41 a	13 c	49.5 ab	23.0 d
Late	NR-400	2500 d	131 d	200 cd	32 c	35 a	42.2 e	27.2 a
	NR-397	2840 c	137 c	215 c	35 b	28 b	46.5 c	24.5 c
	NR-379	2340 d	130 d	190 d	31 c	33 a	42.5 e	27.0 a
	NARC-09	2880 c	136 c	210 cd	35 b	25 b	44.6 d	24.7 c
Combined means squares (MS) and significance								
Replication	42778	0.87	65	3.87	5.29	0.02	0.02	
Sowing date	6917634**	5581.50**	252971**	198.37**	1504.17**	149**	22.23**	
Cultivars	364234**	13.50**	1229*	37.37**	52.50**	15.65**	10.91**	
Sowing date x Cultivar	6234*	29.50**	141*	1.37*	17.17*	1.02*	0.22*	
Error	15207	4.02	164	1.87	3.58	1.12	0.04	

Means followed by different letter(s) in each category with in a column are significantly different at 5 % level of probability.

* = $p < 0.05$ ** = $p < 0.01$

DTM = Days to maturity

1000 GW = 1000 grain weight

Mean LC = Mean leaf chlorophyll

Mean CT = Mean canopy temperature

Mean Leaf SPAD Value

Late sowing significantly reduced ($p < 0.05$) mean leaf SPAD value (11%) as compared to normal sowing during grain filling periods (Table 2). Among genotypes, degradation in mean leaf chlorophyll of cultivars NR-397 and NARC-09 was significantly lower ($p < 0.05$) than NR-379 and NR-400. Maximum mean leaf chlorophyll value of both sowing dates was showed by NR-397 (48.5) followed by NARC-09 (47), NR-400 (45.2) and NR-379 (45) as shown in Table 2.

The results showed a positive correlation (0.98) between average flag leaf chlorophyll values and grain yields of genotypes. Cultivars with higher leaf chlorophyll values produced maximum average grain yields (Fig 2). Significantly low leaf chlorophyll degradation in NR-397 and NARC-09 have the indication of more stable photo system which ultimately lead to better photosynthetic activity, more dry matter accumulation and ultimately higher grain yields as compared to other two tested genotypes. A positive correction between grain yields and better leaf chlorophyll retention of wheat genotypes was also observed by Gutiérrez-Rodríguez *et al.*, (2004) under stressed environment.

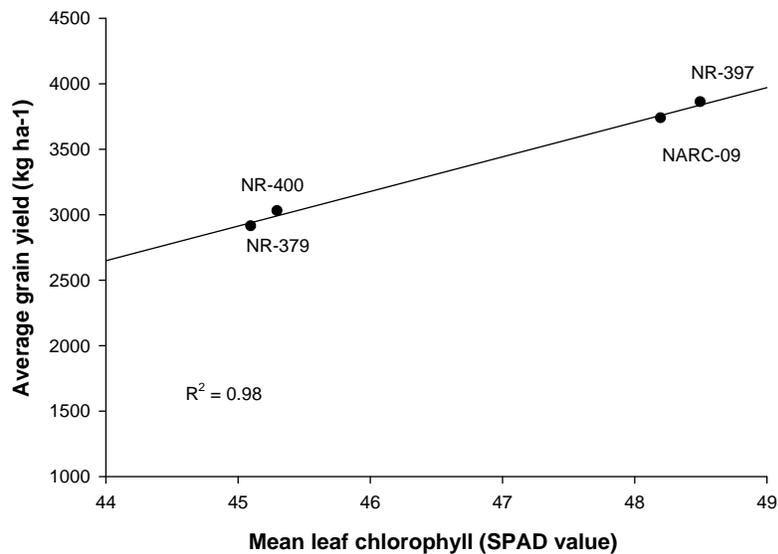


Fig. 2. Correlation between mean leaf chlorophyll and average grain yield of wheat genotypes

Days to Maturity

All cultivars under study took more mean days to physiologically mature (164) under normal growing conditions as compared to late sowing (134). Mean values for days to maturity were also significantly different ($p < 0.05$) among cultivars. Genotypes NR-397 and NARC-09 took significantly more mean days ($p < 0.05$) to reach physiological maturity (152 and 153, respectively) as compared to NR-379 and NR-400 (147 each; Table 2). Reduced life span of genotypes under late planting conditions indicated forced maturity driven by high temperatures at later growth stages. Under normal growing conditions (November sowing), the grain filling period of genotypes lasts from 45 to 58 days than under late planting (30 to 38 days). However, variation among cultivars exists to prolong its grain filling duration under high temperature conditions of late planting, as NR-397 and NARC-09 took 5-7 more days to reach physiological maturity as compared to rest of cultivars which may have inherent character to tolerate high temperature stress at grain filling period. Similar findings were also reported by Khan *et al.* (2007).

Spike Sterility (%)

The spike sterility percentage was significantly influenced ($p < 0.05$) by genotype and planting date. Mean sterility was higher in the late sown crop (30%) as compared to normal sowing (14%). Among genotypes, NARC-09 showed less mean sterility (19%) followed by NR-397 (21%), NR-379 (24%) and NR-400 (26% Table 2). Post-anthesis high temperature stress seems to most plausible reason for higher floret sterility (Rawson, 1986) and grain mortality (Sikder and Paul, 2010) under late planting conditions. Abortion of kernels at high temperature may be due to reduced photosynthetic activity and decreased supply of carbohydrates which leads to increased spike sterility. Floret sterility variation among cultivars was also found by Rawson (1986) in wheat.

Number of Spikes m^{-2}

Significant adverse effect ($p < 0.05$) of late sowing was observed on number of spikes m^{-2} for all the genotypes under late planting conditions as compared to normal planting. Overall, about 25% reduction in spike m^{-2} was noticed in late planted crop as compared to normal. Mean values of spikes m^{-2} were also varied among cultivars. Again NR-397 and NARC-09 produced maximum productive tillers under both normal and late sowing conditions (Table 2). Khan *et al.* (2007) and Shahzad *et al.* (2002) also reported reduced fertile tillers population in late planted wheat and variation among cultivars.

1000 Grain Weight (g)

Significant reduction ($p < 0.05$) in 1000 grain weight was observed in all genotypes when sowing was delayed from mid November to mid December; however extent of reduction was different among genotypes. Cultivars NR-397 and NARC-09 produced significantly higher ($p < 0.05$) grain weight under both normal and late planting conditions as compared to rest of two genotypes (Table 2). Variability among genotypes exists for production of higher grain weight as compare to others under stressed environment. Some genotypes have the ability to produce higher seed weight as compared to others under high temperature stress of late sowing (Mehboob *et al.* 2005; Khan *et al.*, 2007). Reduction in grain weight of some genotypes under stress condition may be attributed to grain mortality due to high temperature injury at reproductive growth stages. Similar results were also reported by Al-Khatib and Paulsen (1984), Calderini *et al.* (1999) and Wardlaw (2002).

Grain yield ($kg ha^{-1}$)

Normal planting time (15 November) produced significantly higher ($p < 0.05$) grain yield (3714) as compared to late planted crop (2640) which was sown on December 15. Mean values for grain yields of both sowing dates were also observed significantly different ($p < 0.05$) among cultivars. The mean grain yields of NR-397 (3395) and NARC-09 (3370) were consistently higher ($p < 0.05$) as compared to NR-400 (3050) and NR-379 (2910) as shown in Table 2. Under late planting conditions, NARC-09 produced maximum yield (2840) followed by NR-397 (2840), NR-400 (2500) and NR-379 (2340). According to results of this study significantly higher ($p < 0.05$) grain yields of NR-397 and NARC-2009 under variable rainfed growing conditions may be attributed to the maintenance of their low canopy temperature, higher flag leaf chlorophyll retention, lower spike sterility and better grain weight especially in more stressful late sowing conditions at reproductive growth stages. Reduction in grain yield of cultivars and significant variation among genotypes is also observed by many researchers (Jain *et al.*, 1992; Kumar *et al.*, 1994; Arain, 1999; Okuyama *et al.*, 2005) under late planting as compared to normal planting (Mehboob *et al.*, 2005; Khan *et al.*, 2007).

CONCLUSION AND RECOMMENDATIONS

In conclusion, late sown wheat crop was more exposed to high temperature stress during grain filling period which caused grain mortality and lead to reduced grain yields of all genotypes, However, cultivars NR-397 and NARC-09 produced significantly higher grain yields under both growing conditions (normal and late). These two genotypes might have inherent tolerance against temperature stress under rain-fed conditions. Genetic potential of genotypes to tolerate environmental stress proved to be more important factor for better wheat productivity under stressed environment. Moreover, canopy temperature and leaf chlorophyll measurements under field conditions proved pretty useful phenotypic techniques to evaluate genotypes for better productivity under stressed environment.

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