# Photosynthetic Functioning As A Selection Criteria For Maximum Yield Potential In Some Wheat Genotypes Under Late Planting Heat Stress Conditions.

***Radhika* and Thind S K***
Department of Botany, College of Basic Sciences and Humanities,Punjab Agricultural University, Ludhiana-141004, India
Punjab Agricultural University, Ludhiana, India.
***Email :** bansalradhika510@gmail.com

**Abstract**

Heat stress had profound effect on the photosynthetic efficiency. This study demonstrated a large degree of genotypicvariability in net photosynthesis, stomatal conductance and rate of transpiration among 40 wheat genotypes afteranthesis under late planting high temperature field conditions when compared with the timely sown. CTD measured inthe flag leaf was significantly correlated with grain yield when measured after anthesis, with correlation coefficients of0.389* ($P<0.01$) and 0.602** ($P<0.01$) for timely and late sown respectively. In certain genotypes cooler canopy andhigh stomatal conductance after anthesis would be assumed as the basic morpho-physiological criteria for higher grainyield under heat stressed conditions. Ci measured in the flag leaf was significantly correlated with grain yield whenmeasured at anthesis only in late sown conditions, with correlation coefficients of 0.320* ($P<0.01$). There was foundthe overall decrease in the P(n) with the delay in sowing. Tr measured in the flag leaf was significantly correlated withgrain when measured after anthesis, with correlation coefficients of 0.718*** ($P<0.0001$) and 0.502** ($P<0.01$) fortimely and late sown respectively. This study showed that the photosynthetic rate of wheat genotypes grown under lateplanting field conditions varies greatly and is significantly associated with grain yield. The associations found betweennet photosynthesis, stomatal conductance, grain yield, contribute significantly to our understanding of the mechanismsdetermining potential productivity in superior germplasm under hot conditions.The studied correlation suggest thatPn, and Tr were found to be effective traits defining wheat genotypes adapted to production systems prone to hightemperature stress during the anthesis period.

**Keywords:** wheat, heat stress, canopy temperature, photosynthesis P(n), transpiration Tr, stomatal conductance (gs).

## Introduction

Photosynthesis was one of the most vital physiological processes contributing to plant growth and productivity of crop for food. In other words, photosynthetic capacity in crop plants was the primary component of dry matter productivity. However rate of photosynthesis varies with the change in environmental factors thereby affecting the plant growth and yield (Natr and Lawlor 2005). Although photosynthesis is fundamental to plant productivity, many other factors modify the magnitude of productivity attained in the field. Maximum photosynthesis takes place at flag leaf stage of wheat contributing toward final yield. Photosynthetic energy conversion describes the whole photosynthetic process from light capture on the photosynthetic membranes to $CO_2$ assimilation and its subsequent metabolism in the chloroplast and elsewhere. Most of the minimum sets of measurements and monitoring necessary to allow modeling of productivity are oriented towards photosynthetic processes. The recommended data inputs are $CO_2$, temperature, precipitation, radiation and vapour pressure. These inputs are required to describe and model the following key properties: $CO_2$ flux, net primary production, $H_2O$ flux and vapour exchanges, vegetation structure including leaf area index and carbon distribution above and below the ground. Measurement of $CO_2$ uptake provides an alternative and direct method of measuring carbon exchange with important advantages: it is instantaneous and non- destructive, and can provide an unambiguous and direct measure of the net rate of photosynthetic carbon assimilation. The majority of $CO_2$ exchange studies have involved enclosure methods, i.e.

enclosure of leaf in transparent chamber. The rate of $CO_2$ by the material enclosed is determined by measuring the change in the $CO_2$ concentration of the air flowing across the chamber. Under mild stress conditions, small leaves could, however, represent an important disadvantage in terms of photosynthetic activity (Zaharieva *et al* 2001). Reduced photosynthesis results in declined light harvesting and generation of reducing powers, which were the source of energy for dark reactions of photosynthesis. Different physiological traits such as stem reserves mobilization, canopy temperature depression (Amani *et al* 1996) and stomatal conductance (Reynolds *et al* 1994) have been associated with performance of wheat under high temperature level which could also be used as selection criteria to identify heat tolerant genotypes. Canopy temperature depression (CTD) and stem reserve mobilization (SRM) capacity of wheat cultivars were evaluated by Sikder and Paul (2010). Genetic variability existed for CTD among the wheat germplasms under heat stress condition. The performance in CTD of different cultivars was reflected to their yield performance. Potential to keep canopy cool is one of the important traits of high temperature tolerant wheat genotypes. This is reflected by canopy temperature depression which is expressed as difference between the ambient temperature and the canopy temperature. Heat tolerant (HT) cultivars showed higher CTD than the heat sensitive (HS) cultivars. It means that HT cultivars had greater ability to maintain cooler canopy environment than the HS cultivars. Most research has focused on measuring light saturated net carbon exchange rate (Amax) of individual leaves. Strong relationship between Amax, stomatal conductance (gS), internal $CO_2$ concentration and yield has been reported under warm, irrigated environments (Reynolds *et al* 2000) as well as under temperate conditions. Several physiological process reduce the amount of net carbon fixed that is available for growth, the main being the respiration of assimilates during the dark period. High irradiance not only saturates photosynthesis, but also subjects the exposed flag leaf to high light stress leading to photo-inhibition. Photo-inhibition potentially reduces the radiation-conversion efficiency of the crop and leads to lower rates of $CO_2$ assimilation. Higher plants transform sunlight to chemical energy by means of photosynthesis. During the process, plants fix carbon dioxide and release oxygen while coping with the loss of water. In recent years, researchers show that some physiological criteria such as stomatal conductance (Bahar *et al* 2009), photosynthetic rate (Koc *et al* 2003), canopy temperature depression (Bahar *et al* 2008), and cholorophyll content (Yıldırım *et al* 2011) provide a gain on wheat. Physiological researches showed that photosynthetic rate of flag leaf, stomatal conductance were the complementary selection criteria for heat stress tolerance under Mediterranean conditions (Koc *et al* 2008). It had been pronounced that CTD is usually expressed as canopy temperature (Tc) minus air temperature (Ta), and it is positive when the canopy is cooler than the air. It has been used as a selection criterion in wheat breeding in terms of heat and drought stress tolerance (Reynolds *et al* 2001; Balota *et al* 2007). According to Munjal and Rana (2003), cooler canopy and high stomatal conductance at grain filling period would be assumed as the basic morpho-physiological criteria for higher grain yield under heat stressed conditions. Balota *et al* (2008) reported that wheat cultivars with high CTD showed a trend of higher yield under heat stress. Bahar *et al* (2008) showed durum wheat (*Triticum durum* L.) stayed cooler than bread wheat genotypes under heat stress conditions. CTD was mostly high positive significant correlated with grain yield (Ayeneh *et al* 2002) and stomatal conductance (Amani *et al* 1996). CTD was correlated with yield under drought stress (Blum, 1988) and heat, irrigated conditions (Reynolds *et al* 1994). They also recommended that CTD could be used to identify plants with cooler canopies with the aim of yield increasing under non-stressed conditions. Stomatal conductance was a key factor affecting photosynthesis in plants (Medlyn *et al* 2001) as it is the speed of passage of water through pores of plants. Stomatal aperture in this regard holds a vital place as water and nutrients absorbed through stomata, which then be used for photosynthetic efficiency. Stomatal conductance was strongly influenced under variable sowing dates and environments. Since declined stomatal conductance recorded under stress conditions therefore, it is concluded that under stress stomata remained closed and limited gas exchange occurred (Jaleel *et al* 2009). Ahmed *et al* (2010), reported reduction in photosynthetic efficiency and stomatal conductance and ultimately lower yield under variable weather conditions.Transpiration rate, an important index of physiological attributes strongly influenced under continuously changing climatic scenarios and crop internal factors including stomatal aperture and hydraulic status of plants. Maximum transpiration rate led to water circulation and optimum photosynthetic efficiency which consequently increased yield. Likewise, Olszewski *et* al (2008) were of the opinion that transpiration rate and photosynthetic efficiency significantly affected under stress conditions.

**Material and methods**

To observe the effect of sowing date mediated high temperature stress on the photosynthetic efficiency and its correlation with the yield of 40 wheat genotypes (including lines assembled by CIMMYT and some Punjab cultivars), the two periodic field experiments were conducted in the year 2011-2012 and 2012 -2013 with normal sowing (November 30) and late sowing (December 30). All the genotypes were planted in two replications, with a 5-row plot, row length of 2.5 m and 23 cm spacing between rows. Besides, the compact block was used to avoid soil heterogeneity effects and recommended agronomic practices were followed to avoid moisture and other stresses so as to ensure proper expression of different traits. Photosynthetic characters were measured under field conditions using an infrared gas analyzer (IRGA) on flag leaves at 10 DAA positioned at right angles to incident solar radiation. The genotypes were compared for different attributes by estimating critical difference for each attribute**.** The data were analyzed according to the experimental design and correlation coefficients were worked out. Observations for any variable is the mean value of both the periodic studies.

**Table 1: Genotypic identity and cross names of the studied genotypes.**

| GENOTYPE | GID | CROSS NAME |
|---|---|---|
| G1 | 6143836 | OLIMPIA2/SLM |
| G2 | 6056194 | BAV92/SERI |
| G3 | 5968552 | OLIMPIA2/SLM |
| G4 | 6143839 | W15.92/4/PASTOR//HXL7573/2*BAU/3/WBLL1 |
| G5 | 6143868 | SOKOLL/WBLL1 |
| G6 | 6056159 | MEX94.2.19//SOKOLL/WBLL1 |
| G7 | 6143869 | OAX93.24.35//SOKOLL/WBLL1 |
| G8 | 6143870 | PASTOR//HXL7573/2*BAU/3/MEX94.2.19//ATTILA/3*BCN |
| G9 | 6143871 | FRTL/SOKOLL |
| G10 | 6143827 | CNDO/R143//ENTE/MEXI_2/3/AEGILOPS-SQUARROSA (TAUS)/4/WEAVER/5/BORL95/6/2*FRET2 |
| G11 | 2450179 | BAW898 |
| G12 | 6143828 | PARUS/3/CHEN/AE.SQ//2*OPATA |
| G13 | 6056135 | PASTOR//HXL7573/2*BAU/3/CMH82.575/CMH82.801 |
| G14 | 6056142 | SOKOLL/WBLL1 |
| G15 | 6056147 | PASTOR//HXL7573/2*BAU/3/WBLL1 |
| G16 | 6056184 | MEX94.2.19/PUB94.15.1.12 |
| G17 | 6056185 | W15.92/WBLL1 |
| G18 | 6056064 | PUB94.15.1.12/WBLL1 |
| G19 | 6056186 | PUB94.15.1.12/3/FRTL//ATTILA/3*BCN |
| G20 | 6056175 | PUB94.15.1.12/FRTL |
| G21 | 4748166 | BAV92/SERI |
| G22 | 4748122 | BAV92/SERI |

| | | |
|---|---|---|
| G23 | 5899052 | BAV92/SERI |
| G24 | 5899053 | BAV92/SERI |
| G25 | 4748091 | BAV92/SERI |
| G26 | 4748074 | BAV92/SERI |
| G27 | 4748064 | BAV92/SERI |
| G28 | 4748160 | BAV92/SERI |
| G29 | 4748051 | BAV92/SERI |
| G30 | 4748043 | BAV92/SERI |
| G31 | 4748041 | BAV92/SERI |
| G32 | 3895 | SERI M 82 |
| G33 | 447649 | BAVIACORA M 92 |
| G34 | 342030 | SILVERSTAR |
| G35 | 3828890 | WYALKATCHEM |
| G36 | 3827751 | SOKOLL |
| G37 | | PBW343 |
| G38 | | PBW621 |
| G39 | | HD 2967 |
| G40 | | C306 |

**Results and discussion**

Various photosynthetic parameters were studied and it was found that the photosynthetic efficiency of all the studied genotypes decreased significantly with the delay in sowing. Thus the heat stress had profound effect on the photosynthetic efficiency. The CT value ranges from 33.29 to 38.73 under timely sown conditions while its value ranges from 34.71 to 40.17 under late sown conditions (Table 2). Thus there was found the increase in the net CT with the delay in sowing. It may be due to the increase in the environmental temperature at 10 DAA. The lowest CT values were noticed in the EMG while the highest CT measurements were observed in LMG under late sown conditions. As mean, CT values of genotypes showed value of 35.13 and 37.51°C. CT measured was not strongly associated with grain yield when measured after anthesis (Table 3).Canopy temperature depression (CTD) at 10 DAA of 40 wheat genotypes was recorded. From the results it was observed that there existed variations in CTD among the genotypes and growing conditions. In the present study, all the cultivars showed higher CTD at late growing heat stress condition compared to normal growing condition. Overall mean variations (growth seasons, measuring times) of the canopy temperatures of studied wheat genotypes were significantly different. CTD ranged from 3.49 to 8.93 °C in timely sown and from 4.01 to 9.47 °C in late sown genotypes for average of measurements (Table 2). Thus, plants had possibility of cooling by the transpiration of the stomata. Similar results were reported by a group of researchers Reynolds *et al* (1994) that potential to keep canopy cool is one of the important traits of high temperature tolerant wheat genotypes. This is reflected by canopy temperature depression which is expressed as difference between the ambient temperature and the canopy temperature. This trait shows high genetic correlation with yield and high values of proportion of direct response to selection indication that the trait is heritable. It was reported that genetic variability in CTD among the wheat genotypes which was more conspicuous at heat stress and there was a significant correlation between grain weight per spike and CTD. CTD measured in the flag leaf was significantly correlated with grain yield when measured after anthesis, with correlation coefficients of 0.389* ($P<0.01$) and 0.602** ($P<0.01$) for timely and late sown respectively (Table 3).

Stomatal conductance was a key factor affecting photosynthesis in plants. In general, gs was also seriously affected by short-term high temperature stress. Presently, Stomatal conductance (gs) was measured and genotypes show statistically differences for gs on both plantings and their mean. Nevertheless gs values ranged from .104 to .682

mmol $H_2O$ $m^{-2}s^{-1}$ and .085 to .455 mmol $H_2O$ $m^{-2}s^{-1}$ at 10 DAA under timely and late sown conditions, respectively (Table 2). Results revealed that all genotypes showed high measure values under timely sown conditions for gs. The reason of this difference was stomatal conductance values of flag leaves have rapidly decreased by the leaf senescence after anthesis period. Since declined stomatal conductance recorded under stress conditions therefore, it is concluded that under stress stomata remained closed and limited gas exchange occurred (Jaleel *et al* 2009). The measurements revealed genotypic differences on gs due to different sowing conditions at same stage. Seri M 82, Silvestar, C306,HD 967 and PBW 343 had higher value of gs under timely sown conditions at anthesis stage, but the decrease in the gs took place due to elevated temperature in late planting at the anthesis stage. From among the genotypes C306, Sokoll,Wyalketchem and PBW 621 were found superior regarding the maintaince of gs under late sown high temperature stress conditions.

There was found the overall decrease in the Ci value. The mean value decreases from 290 to 195. Internal CO2 (Ci) value values ranged from 202 to 351 mmol $H_2O$ $m^{-2}s^{-1}$ and 135 to 329 mmol $H_2O$ $m^{-2}s^{-1}$ at 10 DAA under timely and late sown conditions, respectively(Table 2). Ci measured in the flag leaf was significantly correlated with grain yield when measured at anthesis only in late sown conditions, with correlation coefficients of 0.320* ($P<0.01$)(Table 3).

Transpiration rate (Tr), an important index of physiological attributes strongly influenced under continuously changing climatic scenarios and crop internal factors including stomatal aperture and hydraulic status of plants. Maximum transpiration rate led to water circulation and optimum photosynthetic efficiency which consequently increased yield. Tr of Wheat genotypes planted in the late varied inconsistently as compared to the timely sown. Tr values ranged from 2.74 to 7.70 mmol $H_2O$ $m^{-2}s^{-1}$ and 1.18 to 6.73 mmol $H_2O$ $m^{-2}s^{-1}$ at 10 DAA under timely and late sown conditions, respectively (Table 2). Likewise, Olszewski *et* al (2008) were of the opinion that transpiration rate and photosynthetic efficiency significantly affected under stress conditions. Silverstar often had high Tr, however, C306 and Sokoll often had low values of Tr under timely sown conditions. Under late sown conditions from among the 40 genotypes, C306, Sokoll, Baviacora M 92 and PBW 621 were found to be able to maintain their net Tr under heat stressed conditions. Tr measured in the flag leaf was significantly correlated with grain when measured after anthesis, with correlation coefficients of 0.718*** ($P<0.0001$) and 0.502** ($P<0.01$) for timelyand late sown respectively (Table 3).

Photosynthetic rates of all the studied wheat genotypes that were planted late decreased gradually at anthesis as compared to the timely planting. P(n) values ranged from 4.40 to 10.98 mmol $CO_2$ $m^{-2}s^{-1}$ and 2.63 to 11.26 mmol $CO_2$ $m^{-2}s^{-1}$ at 10 DAA under timely and late sown conditions, respectively(Table 2). From the proceeding study it is concluded that the highest value for P(n) was found to be more under late sown conditions. There was found the overall decrease in the P(n) with the delay in sowing. Silverstar had the maximum Pn under the timely sown conditions but it was found to be the weak candidate under the late sown conditions. From among the genotypes Wyalkatchem, Sokoll, C306 and PBW 621 can maintain their net Pn rate under both the timely and late sown conditions. The mean net Pn of timely sown showed a highly significant ($P<0.01$), positive correlation ($r$ =0.563**) with grain yield (Table 3).

Using the mean values across treatments and experiments for each genotype, the correlation of GY with all variables measured. From this, it is clear that the variables GY, Pn, gs content were all significantly associated among one another. The change in the gs was not associated with GY, as indicated by the low correlation coefficients (Table 3).The results showed that short-term high temperature stress produced a reduction the morpho-physiological traits in December sown as compared to the November sown. It is concluded that all morpho-physiological traits that such genotypes as C306, Sokoll, Baviacora M92 can maintain their homeostasis under variable planting conditions at the anthesis stage as compared to the other genotypes such as BAW 898, Silverstar, PBW 343. The studied correlation suggest that Pn, and Tr were found to be effective traits defining wheat genotypes adapted to production systems prone to high temperature stress during the anthesis period.

**Table 2: Effect of sowing date mediated heat stress after anthesis on various photosynthetic traits of studied wheat genotypes.**

| GENOTYPE | CT (°C) | | CTD (°C) | | g(s) mmol $H_2O$ $m^{-2}s^{-1}$ | | C(i) mmol $H_2O$ $m^{-2}s^{-1}$ | | Tr mmol $H_2O$ $m^{-2}s^{-1}$ | | P(n) mmol $CO_2$ $m^{-2}s^{-1}$ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Timely | Late | Timely | Late | Timely | Late | Timely | Late | Timely | Late | Timely | late |
| **G1** | 35.02 | 37.64 | 5.22 | 6.94 | 0.323 | 0.273 | 316 | 239 | 6.69 | 5.87 | 8.87 | 7.11 |
| **G2** | 34.33 | 36.54 | 4.53 | 5.84 | 0.312 | 0.265 | 348 | 246 | 6.28 | 6.73 | 8.01 | 6.76 |
| **G3** | 37.38 | 38.23 | 7.58 | 7.53 | 0.131 | 0.136 | 328 | 225 | 5.37 | 3.64 | 4.40 | 3.62 |
| **G4** | 34.56 | 36.54 | 4.76 | 5.84 | 0.242 | 0.182 | 309 | 228 | 6.46 | 3.96 | 10.71 | 8.10 |
| **G5** | 33.53 | 37.50 | 3.73 | 6.80 | 0.228 | 0.226 | 267 | 249 | 7.70 | 5.66 | 10.56 | 11.26 |
| **G6** | 36.48 | 38.56 | 6.68 | 7.86 | 0.485 | 0.249 | 258 | 166 | 5.42 | 1.95 | 6.71 | 4.85 |
| **G7** | 35.82 | 37.42 | 6.02 | 6.72 | 0.464 | 0.137 | 318 | 169 | 4.02 | 3.58 | 7.75 | 3.24 |
| **G8** | 33.29 | 38.22 | 3.49 | 7.52 | 0.275 | 0.206 | 300 | 245 | 7.08 | 4.96 | 10.61 | 6.93 |
| **G9** | 34.21 | 36.43 | 4.41 | 5.73 | 0.227 | 0.181 | 337 | 280 | 4.65 | 3.26 | 10.53 | 4.81 |
| **G10** | 34.64 | 39.64 | 4.84 | 8.94 | 0.270 | 0.219 | 304 | 201 | 4.49 | 3.57 | 8.12 | 6.35 |
| **G11** | 33.90 | 36.54 | 4.10 | 5.84 | 0.175 | 0.107 | 309 | 262 | 4.10 | 3.02 | 7.44 | 6.08 |
| **G12** | 36.13 | 37.98 | 6.33 | 7.28 | 0.184 | 0.168 | 326 | 274 | 5.38 | 4.77 | 9.64 | 3.60 |
| **G13** | 36.21 | 40.17 | 6.41 | 9.47 | 0.682 | 0.455 | 239 | 140 | 5.43 | 3.66 | 9.19 | 3.04 |
| **G14** | 38.73 | 38.76 | 8.93 | 8.06 | 0.405 | 0.278 | 250 | 180 | 4.20 | 2.95 | 9.02 | 6.43 |
| **G15** | 36.37 | 37.10 | 6.57 | 6.40 | 0.136 | 0.121 | 274 | 261 | 5.07 | 4.46 | 7.99 | 5.86 |
| **G16** | 34.69 | 36.01 | 4.89 | 5.31 | 0.151 | 0.146 | 267 | 228 | 5.03 | 4.73 | 9.75 | 3.56 |
| **G17** | 34.12 | 36.29 | 4.32 | 5.59 | 0.201 | 0.158 | 300 | 284 | 6.48 | 2.76 | 8.30 | 3.77 |
| **G18** | 34.91 | 36.50 | 5.11 | 5.80 | 0.304 | 0.156 | 321 | 318 | 6.67 | 4.20 | 8.85 | 3.89 |
| **G19** | 36.76 | 37.84 | 6.96 | 7.14 | 0.173 | 0.114 | 217 | 197 | 3.38 | 2.57 | 8.24 | 2.63 |
| **G20** | 34.93 | 37.81 | 5.13 | 7.11 | 0.178 | 0.162 | 326 | 135 | 6.68 | 2.20 | 9.43 | 4.66 |
| **G21** | 36.27 | 38.65 | 6.47 | 7.95 | 0.349 | 0.153 | 351 | 248 | 5.81 | 2.82 | 10.36 | 3.39 |
| **G22** | 35.02 | 37.50 | 5.22 | 6.80 | 0.275 | 0.251 | 305 | 226 | 3.15 | 2.64 | 5.85 | 3.61 |
| **G23** | 34.38 | 37.59 | 4.58 | 6.89 | 0.178 | 0.146 | 288 | 170 | 4.78 | 3.39 | 9.45 | 6.43 |
| **G24** | 34.93 | 38.54 | 5.13 | 7.84 | 0.197 | 0.135 | 214 | 194 | 6.15 | 4.55 | 9.77 | 8.38 |
| **G25** | 34.98 | 35.99 | 5.18 | 5.29 | 0.164 | 0.112 | 301 | 193 | 3.7 | 2.39 | 7.69 | 4.45 |
| **G26** | 34.34 | 35.40 | 4.54 | 4.70 | 0.292 | 0.260 | 313 | 299 | 5.8 | 5.32 | 10.82 | 8.91 |
| **G27** | 35.08 | 38.76 | 5.28 | 8.06 | 0.265 | 0.223 | 300 | 157 | 3.64 | 2.46 | 7.77 | 6.42 |
| **G28** | 35.29 | 36.20 | 5.49 | 5.50 | 0.173 | 0.176 | 312 | 201 | 2.74 | 1.93 | 7.87 | 2.94 |
| **G29** | 36.34 | 39.45 | 6.54 | 8.75 | 0.171 | 0.178 | 260 | 221 | 3.29 | 1.18 | 7.35 | 4.3 |
| **G30** | 36.37 | 38.71 | 6.57 | 8.01 | 0.147 | 0.127 | 338 | 204 | 5.246 | 2.53 | 10.74 | 4.25 |
| **G31** | 33.72 | 34.71 | 3.92 | 4.01 | 0.372 | 0.246 | 341 | 329 | 5.02 | 2.96 | 6.63 | 4.68 |
| **G32** | 34.78 | 36.54 | 4.98 | 5.84 | 0.168 | 0.153 | 253 | 208 | 5.08 | 5.03 | 9.23 | 7.35 |
| **G33** | 33.84 | 37.66 | 4.04 | 6.96 | 0.198 | 0.185 | 244 | 203 | 3.91 | 2.56 | 8.88 | 7.54 |
| **G34** | 34.69 | 35.98 | 4.89 | 5.28 | 0.195 | 0.128 | 283 | 282 | 5.20 | 3.68 | 8.25 | 5.65 |
| **G35** | 34.43 | 39.66 | 4.63 | 8.96 | 0.105 | 0.096 | 202 | 195 | 4.976 | 3.26 | 10.98 | 6.61 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **G36** | 35.28 | 38.66 | 5.48 | 7.96 | 0.192 | 0.168 | 231 | 201 | 4.51 | 2.57 | 7.46 | 4.24 |
| **G37** | 34.53 | 35.58 | 4.73 | 4.88 | 0.186 | 0.139 | 285 | 253 | 6.12 | 4.23 | 10.07 | 8.23 |
| **G38** | 34.86 | 36.64 | 5.06 | 5.94 | 0.262 | 0.243 | 290 | 173 | 5.67 | 4.32 | 6.47 | 5.87 |
| **G39** | 35.12 | 39.75 | 5.32 | 9.05 | 0.198 | 0.136 | 271 | 232 | 5.02 | 3.66 | 10.19 | 7.22 |
| **G40** | 35.01 | 36.70 | 5.21 | 6.16 | 0.104 | 0.080 | 304 | 279 | 3.92 | 3.45 | 7.43 | 5.63 |
| **MEAN** | **35.13** | **37.51** | **5.33** | **6.81** | **.243** | **.181** | **290** | **194** | **5.10** | **3.58** | **8.68** | **5.56** |
| **LSD 5%** | **1.109** | **1.335** | **1.109** | **1.332** | **.1149** | **.0692** | **6.051** | **7.451** | **1.173** | **1.197** | **1.534** | **1.944** |
| **CV*%** | **3.2** | **3.6** | **20.8** | **19.6** | **27.2** | **30.1** | **13.2** | **21.0** | **23.0** | **33.4** | **17.7** | **28.7** |

*Coefficient of Variation (%) which indicates the reliability of an experiment. The lower the CV% value indicates the higher the reliability.

LSD (5%) represents the minimal difference between the genotypes which is statistically significant at the 5% level.

Data showed in the table is the mean of periodic experiments conducted in the year 2011-12 and 2012-13

**Table 3: Correlation coefficients (r) between grain yield (GY) and morpho-physiological traits in 40 wheat genotypes under timely and late sown conditions**

| Planting condition | variable | By variable | r |
|---|---|---|---|
| **Timely sown** | **GY** | **CT** | **0.091** |
| | | **CTD** | **0.389*** |
| | | **Ci** | **0.072** |
| | | **P(n)** | **0.563**** |
| | | **gs** | **0.253** |
| | | **Tr** | **0.718***** |
| **Late sown** | **GY** | **CT** | **0.080** |
| | | **CTD** | **0.602**** |
| | | **Ci** | **0.320*** |
| | | **P(n)** | **-0.137** |
| | | **gs** | **-0.190** |
| | | **Tr** | **0.502**** |

****,*** significant at .01 and .001 probability levels, respectively.**

**ACKNOWLEDGEMENT**

First author acknowledge the Inspire program Department of Science and Technology, Ministry of Science and Technology,Technology Bhavan, New Mehrauli Road, New Delhi-110016.We are highly grateful to the staff of the field area department of Botany, for maintaining the experimental plants.

**CONFLICT OF INTEREST**

Author declares no conflict of interests.

**REFRENCES:**

Ahmed M, Hassan F U, Aslam M, Akram M N and Aslam M A (2010). Photosynthesis of spring wheat (Triticum aestivum) in rainfed ecology of Pakistan. *African J. Biotech* **9**: 7495-7503.

Amani I, Fischer R A and Renolds M P (1996) Evaluation of canopy temperature as a screening tool for heat tolerance in spring wheat. *Journal of Agronomy & Crop Science* **176**:119-129.

Ayeneh A, Ginkel M, Reynolds MP, Ammar K (2002). Comparison of leaf, spike, peduncle, and canopy temperature depression in wheat under heat stress. Field Crops Res., 79: 173-184.

Bahar B, Yildirim M, Barutcular C (2009). Relationships between stomatal conductance and yield components in springdurum wheat under Mediterranean conditions. Notulae Botanicae Horti Agrobotanici Cluj-napoca, 37(2): 45-48.

Bahar B, Yildirim M, Barutcular C, Genc I (2008). Effect of canopy temperature depression on grain yield and yield components in bread and durum wheat. Notulae Botanicae Horti Agrobotanici Cluj-napoca, 36(1): 34-37.

Balota M, Payne WA, Evet SR, Lazar MD (2007). Canopy temperature depression sampling to assess grain yield and genotypic differentation in winter wheat. Crop Sci., 47: 1518-1529.

Balota M, Payne WA, Evet SR, Peters TR (2008). Morphological and physiological traits associated with canopy temperature depression in three closely related wheat lines. Crop Sci., 48: 1897-1910.

Blum A (1988). Plant Breeding for Stress Environments. CRC Press, Boca Raton, p. 72.

Jaleel C A, Manivannan P, A. Wahid, M. Farooq, R. Somasundaram and R. Panneerselvam, 2009. Drought stress in plants: a review on morphological characteristics and pigments composition. Int. J.Agric. Biol., 11: 100-105

Koc M, Barutcular C and Tiryakioglu M (2008). Possible heat-tolerant cultivar improvement through the use of flag leaf gas exchange traits in a Mediterranean Environment. J. Sci. Food Agric.Res., 88: 1638-1647.

Koc M, Barutcular C, Genc I (2003). Photosynthesis and productivity of old and modern durum wheats in a Mediterranean Environment. Crop Sci., 43(6): 2089-2097.

Medlyn, B.E., C.V.M. Barton, M.S.J. Broadmeadow, R. Ceulemans, A. De, P. Forstreuter, M. Freeman, S.B. Jackson, S. Kellomaki, E. Laitat, A. Rey, P. Roberntz, B.D. Sigurdsson, J. Strassemeyer, K. Wang, P.S. Curtis and P.G. Jarvis, 2001. Stomatal conductance of forest species after long-term exposure to elevated CO2 concentration: a synthesis. New Phytol., 149: 247-264

Munjal R and Rana RK (2003). Evaluation of physiological traits in wheat (Triticum aestivum L.) for terminal high temperature tolerance. In: Proceedings of the Tenth International Wheat Genetics Symposium, Classical and Molecular Breeding, Poestum, Italy, 2 (3): 804-805.

Natr L and Lawlor D W (2005) Photosynthetic plant productivity In: H and Book Photosynthesis, 2nd (Ed): M Pessarakli C R C Press, New York, USA, Pp 501-524.

Olszewski, J., A. Pszczolkowska, T. Kulik, G. Fordonski, K. Plodzien, A. Okorski and J. Wasielewska, 2008. Rate of photosynthesis and transpiration of winter wheat leaves and ears under water deficit conditions. Pol. J. Natur. Sc., 23: 326-335.

Reynolds M P, Balota M, Delgado M I B, Amani I and Fischer R I (1994) Physiological and morphological traits associated with spring wheat yield under hot, irrigated conditions. *Australian Journal of Plant Physiology* **21**: 717-730.

Reynolds M P, Van Ginkel M and Ribaut J M (2000) Avenues for genetics modification of radiation use efficiency in wheat Avenues for genetics modification of radiation use efficiency in wheat. *J Exp Bot* **51**: 459-473.

Reynolds MP, Nagarajan S, Razzaque MA and Ageeb OAA (2001). Breeding for adaptation to environmental factors, heat tolerance. In: Reynolds MP, Ortiz-Monasterio I, McNab A (eds.) Application of physiology in wheat breeding, Cimmyt, Mexico, p. 124-125.

Sikder S and Paul N K (2010) Evaluation of heat tolerance of Wheat cultivars through physiological approaches. *Thai Journal of Agricultural Science* **43**(4):251- 258.

Zaharieva M, Gaulin E, Havaux M, Acevedo E and Monneveux P (2001) Drought and heat responses in the wild wheat relative *Aegilops geniculata* Roth. *Crop Sci* **41**: 1321-29.