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Physiological, Phenological and Grain Yield Responses in Wheat due to Delayed Sowing

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ABSTRACT

Time of sowing is one of the important factors that govern crop physiology, phenological development along with efficient partitioning of biomass production into economic yields. Due to prolonged duration of preceding crops like rice, cotton, sugarcane and on account of untimately rains, the sowing of succeeding wheat crop gets delayed and is exposed to sub-optimal temperature (High temperature) at establishment, resulting in reduction of not only crop duration but also crop yield. This low yield is due to growth acceleration reduction in duration of crop development stages and carbon starvation due to reduced net assimilation. Genetic progress in increasing the yield potential is closely associated with an increase photosynthetic activity (Rees et al.1993 and Fisher et al.1998).Therefore the present study was conducted to screen photo-synthetic efficient wheat genotypes under delayed sowing condition.

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Introduction

Wheat is an important cereal crop of the world and grown in diverse agro -ecological conditions. Time of sowing is one of the important factors that govern the crop's phenology well as physiology. Due to prolonged duration of succeeding crops like rice and cotton the sowing of wheat gets delayed where it is exposed to sub-optional condition at establishment and supra-optimal conditions at later growth stages which results not only the reduction in the crop duration but also the crop yield (Sardana et al, 1999). The grain filling rate was more thermo-sensitive than the days to anthesis and duration of grain filling in wheat(Blum et al, 2001,Rezaei et al 2015). Net photosynthesis (Pn) is reversibly inhibited at moderately higher temperatures. Long term effects of the high temperature on leaf photosynthesis were associated with either leaf senescence or protein degradation (Banbella and Paulsen, 1998 a, b) or injury to photosystem 2 in wheat (Havaux, 1992). The activation state of Rubisco which is regulated by the activity of the Rubisco Activase appears to be the primary limitation to Pn at high temperatures (Steven and Salvucci, 2004).The cumulative effect of high temperature on the phonological and physiological parameters in turn get reflected in terms of reduced yield of the crop under late sown conditions. The biological yield of the crop was reduced by 28-50% with delay of 30 and 60 days from normal sowing (Singh and Pal,2003).The 31 day delayed sowing in wheat reduced the grain yield by 21% and biomass by 14.7% Tyagi et al ,2003. The results pertaining to yield reduction due to high temperature were also reported by Omara et al, 2004; Bencze et al, 2005.

Material and Methods

In the present study twenty diverse and promising genotypes of wheat were screened for their thermo tolerance potential under field conditions.

High temperature was induced by the manipulation of the sowing dates .The varieties were PII459, PII518, PII543, PII548, PII579, PII580, PII586, P16I6, P1621, P1626, NIAW34, HINDI 62, WH283, WH291, WH423, WH595, WH711, WH712, UP2565, WH730. Phenological observations were determined by subtracting date of sowing from the date of occurrence of the particular phonological stage. Photosynthetic rate (u moles CO2 assimilated m2 sec1) was noted by using portable Infra red gas analyzer(IRGA) PHOTOSYNTHESIS SYSTEM MODEL CIRAS 1. The measurements were done from 10 am to 11.30 am on the sampling dates. Water use efficiency (WUE) was determined by method of Rosenberg and Kriiger, 1993. Grain yield and Harvest index (HI) were determined at the time of harvest.

Results

High temperature reduced the duration of various phenophases which got reflected in terms of reduction in the overall yield of the plant. Days to heading occurred earlier by 2-23 days and days to anthesis by 8-33 days due to late sowing in wheat (figure 1 and 2).

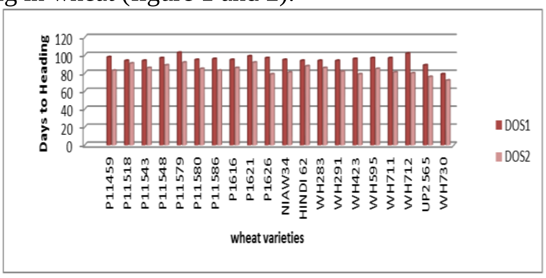

Figure 1.Varietal performance for Days to Heading (DOH) at two sowing dates in wheat.

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C.D. (at 5%) D 2.01 V 6.32 DxV 8.95

D = Date of Sowing; V = Varieties; DxV = Interaction between D and V

Under late sown conditions maximum days required for heading were found in P11579 and P1621 (92 days) and minimum in WH730 (72 days). Highest percentage decline in the duration for heading was found in WH712 (23%) and minimum in P11518 (2%) Table 1. Similarly maximum time period required for anthesis under late sown conditions were found in P11543 (106 days) and minimum (78 days) in UP2565. Delayed sowing decreased the duration for anthesis to the maximum extent in WH 712 (29%) and minimum in P11543 (7%) figure 2.

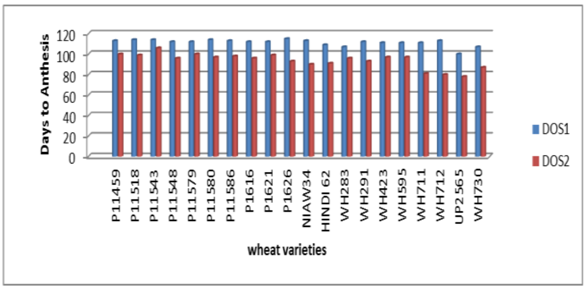

Figure 2. Varietal performance for Days to Anthesis (DOA) at two sowing dates in wheat.

C.D. (at 5%) D 2.24 V 7.07 DxV 9.90

D = Date of Sowing; V = Varieties; DxV = Interaction between D and V

Grain filling duration (GFD) increased approximately 19% due to late sowing (Table-6). At DOS2 (late sowing) GFD was highest in WH-712 (39days) and lowest in WH-283 (14 days). Maximum decline in GFD (62%) was noted in WH-283 and minimum in P11548 (8%) due to late sowing in wheat (figure-3).

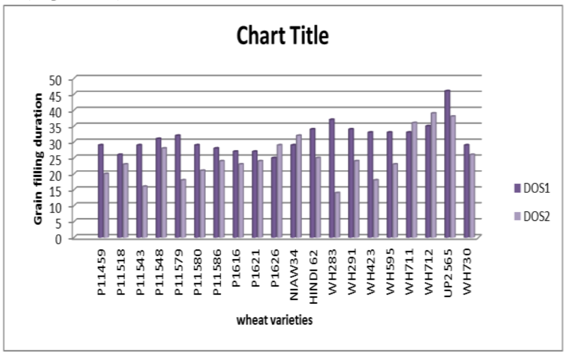

Figure 3. Varietal performance for Grain filling duration (Days) at two sowing dates in wheat.

C.D. (at 5%) D 1.67 V 5.30 DxV 7.49

D = Date of Sowing; V = Varieties; DxV = Interaction between D and V

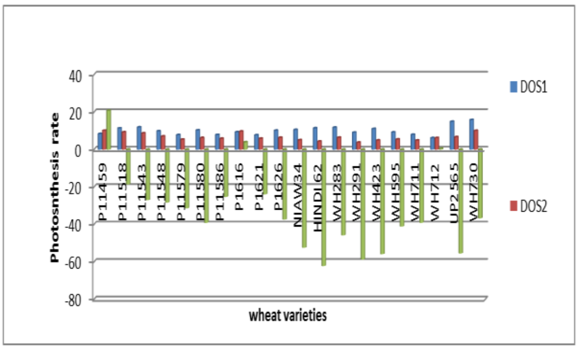

Figure 4. Varietal performance for Photosynthesis (micro moles CO_2 assimilated m^{-2} sec^{-1}) of flag leaf at anthesis (110 DAS) at two sowing dates in wheat.

C.D. (at 5%) D 0.66 V 2.10 DxV 2.96

D = Date of Sowing; V = Varieties; DxV = Interaction between D and V

Net Photosynthesis (Pn) declined up to 35% due to late sowing in wheat except for the few varieties as P11459, P1616 and WH-712 where slight increase in Pn was noted (Table-4).

Under late sown conditions highest Pn was observed in P11459 (10.06) and minimum in WH-291 (3.73). Highest detrimental effect of late sowing on photosynthesis was observed in Hindi 62 (62%) and lowest in P11518 (18%) figure-4.WUE best described as ratio of net photosynthesis (Pn) and transpiration (E),is an important parameter to assess thermotolorance.In comparison to the timely sown plants 14% decrease in WUE was observed due to late sowing in wheat, however, in few varieties as P11459, P11518, P11586, and WH-712 marginal increase in this parameter was noted (Figure-5). At DOS2 (late sowing) maximum WUE was noted for P11518 (3.51) and minimum for WH-291 (1.16). Decline in WUE was highest in WH-291 (59%) and lowest in P1616 (1%) due to delayed sowing in wheat.

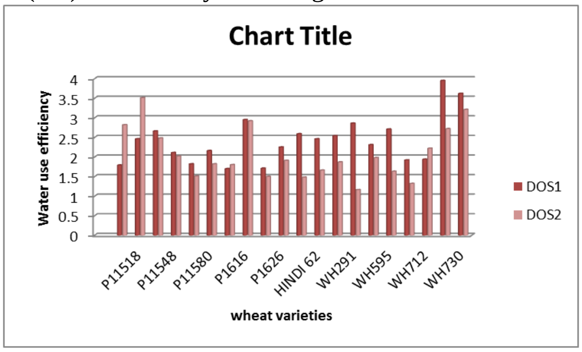

Figure 5. Varietal performance for Water use efficiency at anthesis (110 DAS) at two sowing dates in wheat.

C.D. (at 5%) D 0.38 V 1.14 DxV 1.61

D = Date of Sowing; V = Varieties; DxV = Interaction between D and V

Yield and Yield Component

Grain yield declined upto 30-35% due to late sowing in wheat except in P11459, WH283 and WH 712 where marginal increase in the yield was noted (Table-7). Under late sown conditions maximum yield was noted in WH 730 (0.47) and minimum in WH-711 (0.28). Highest decline (upto 35%) in grain yield was noted in P11518 and minimum 0.44% in P11548 due to late sowing in wheat (Figure-6).

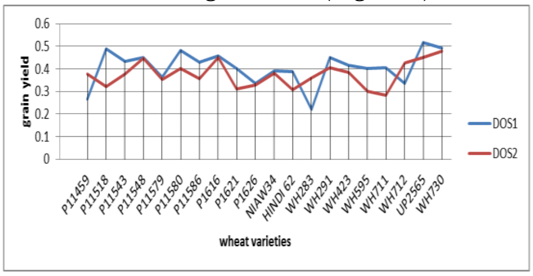

Figure 6. Varietal performance for Grain Yield (kgm^{-2}) at two sowing dates in wheat.

C.D. (at 5%) D 0.19 V 0.63 DxV 0.90

D = Date of Sowing; V = Varieties; DxV = Interaction between D and V

About 6% decrease in H.I was observed due to late sowing except few varieties as P11459, P11548, P1616, P1626, WH-283, WH-712, UP2565 and WH-730 where slight increase in this parameter was noted in wheat(Table-9).

At DOS2 (late sowing) H.I was maximum in WH-730 (0.52) and minimum in Hindi 62 (0.24). Delayed sowing by 28 days resulted highest decline in HI in WH-711(42%) and lowest 6% in NIAW-34 (Figure-7).

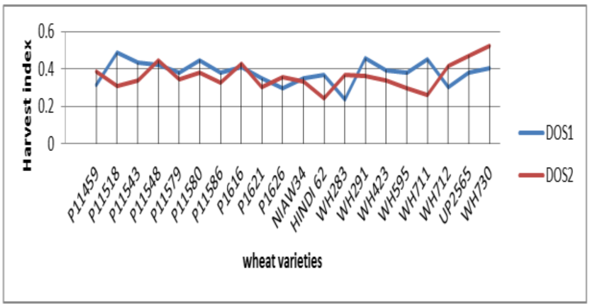

Figure 7. Varietal performance for Harvest index at two sowing dates in wheat.

C.D. (at 5%) D 0.12 V 0.37 DxV NS

D = Date of Sowing; V = Varieties; DxV = Interaction between D and V

Discussion

Temperature stress induced by the manipulation of the sowing dates influences crop phenology and thus final grain yield. Late sown wheat completed heading ,grain filling and crop maturity stages 23 ,03 and 29 days earlier than the normal sown wheat due to high temperatures faced by the crop as a result of delayed sowing(Hossain and Da Silva 2012). The results presented in Figure 1, 2 & 3 show that late sowing reduced days to anthesis and induces early maturity in wheat. Due to reduction in the duration of anthesis, duration of crop maturation as well as grain filling duration were also reduced (figure 3) thus reducing the final grain yield, biomass and harvest index (Figure 6 and 7). The reason behind reduced growth and early flowering under heat stress may be due to sensitivity of metabolic processes that have limit the ability to effectively utilize the available resources (Khan et 2012). The photosynthetic machinery of warm season crops such as wheat is more sensitive to high temperatures and PS II is more sensitive to HT than PSI(Alkhatib and Paulsen, 1999; Feng et al 2014). High temperature induces thylakoid component breakdown, an effect similar to normal senescence pattern. Thylakoid breakdown stimulate imbalance between the photosynthetic reaction rates. Imbalance between PSII and cytochrome b6f complex mediated activities would be particularly damaging during heat stress in wheat (Harding et al,1990) .This is evident from the results presented in Figure 4 where decrease in photosynthesis was noted due to high temperatures induced by late sown conditions . Studies indicate that heat stress leads to dissolution of the peripheral antenna complex of PSII from its core complex (Gounaris et al, 1984) and changes the architecture of antenna (Srivastava et al, 1997).Heat stress may induce inhibition of the electron transfer from QA to QB at the acceptor side (Bukhov et al, 1999). PS 2 activity declined abruptly in chloroplasts ,protoplasts and thylakoids of wheat as the temperature increased from 28-42 0 C.This suggests that difference in PS 2 responses to high temperature are associated with light reactions and the extreme sensitivity of wheat to high temperature may be attributed to PS 2. Lu and Zhang, 2000 reported that high temperature lead to dissociation of the peripheral antenna complex of PS2 from its core components followed by the loss of oxygen evolving complex (OEC).

WUE decreased in almost all the wheat cultivars due to late sowing (Figure 5). Decline in WUE was more in UP 2565 (31%) relative to WH730 where WUE decreased only 11.35% at DOS2.High temperature stress induces water deficit conditions which affects stomatal conductance and photosynthetic activity (figure 4). Thus the stomatal closure induced by the water deficit conditions inhibits transpiration as a result of which the water use efficiency decreases (Tuteja and Sarvjeet 2012). Under severe abiotic stresses WUE decreases and inhibition of the mesophyll metabolism becomes stronger (Taiz and Zeiger, 2002). These observations were in conformity with the results presented in figure 5.

Average grain yield decreased due to late sowing in wheat (figure 6). Among the wheat varieties that were screened in the present study yield reduction due to late sowing ranged from 2-35%. Similar results were also reported earlier by Abrol and Ingram, 1996. This may be due to pre anthesis reserve utilization for protein and carbohydrate synthesis in the grain of wheat when high temperature occurs before at anthesis (Gebbing and Schnyder, 1999). This may be attributed to reduced duration of phenophases (figure 1,2 and 3) , dry matter accumulation in respective sinks and lesser stem reserve mobilization due to reduced rate of photosynthesis (figure 4).

Mean harvest index decreased in wheat due to late sowing (figure 7). The range of decrease in HI varied from 6-36%. Szilvia et al, 2004 reported that 19% loss of grain yield in wheat varieties Emma and Martina was due reduction of 22-37% in Harvest index owing to high temperatures during grain filling. HI reduced to lesser extent in thermo tolerant varieties than the thermo sensitive ones. This may be due to the fact that in the former efficacy of partitioning of the dry matter was sustained to greater extent due to post anthesis high temperature stress . Shubhra et al, 2006 stated that harvest index and test weight could be considered as the potential selection criteria for yield determination under high temperature stress conditions in wheat.

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