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Impact of temperature on phenology and pollen sterility of wheat varieties

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Abstract

Low temperature during reproductive stage of spring wheat causes sterility of pollen grains and reduced yield. Field experiment was conducted during the winter season in the farm of Indian Agricultural Research Institute with wheat crop to study the effect of temperature on phenology and pollen sterility of spring wheat crop. Lower mean temperature during the crop growth period led to enhanced the crop growth period in both aestivum and durum varieties of wheat crop. Results showed that in early sowing treatment pollen sterility percentage was very high (46.1%) in HD 2851 variety. This in turn led to decreased pollen germination and lesser yield in wheat crop. Pollen germination was maximum between mean temperatures of 18°-20°C, while at lower temperatures germination of pollen grains got reduced in all wheat varieties. A good positive correlation was obtained between pollen germination percentage and yield (R^2=0.65) of wheat crop. Data from this experiment indicate that low temperature during reproductive phase could limit wheat yield by affecting its phenology and fertility of pollen grains. Adaptation measures need to be developed for reducing yield loss of wheat in areas experiencing very low temperature during anthesis stage.

Keywords: wheat, pollen sterility, pollen germination, crop growth period, temperature.
Abbreviation: CO_2: Carbon dioxide , DOS: Date of sowing , RBD: Randomized block design.

Introduction

Wheat is the single most important crop on global scale in terms of total harvested weight and amount used for human and animal nutrition (Evans, 1998). Production of wheat has increased more than that of any other crop in the last century. However change in climate associated with rise in carbon dioxide (CO_2) concentration is likely to affect wheat production and thus human food supplies. Temperature during ear emergence and anthesis is considered an important factor limiting yield of wheat crop. Sterility in wheat is regarded as the absence of grain in any floret which grows sufficiently large to contain a grain (Rawson, 1996). Number of grains that develop in an ear is dependent on the number viable florets that are formed and the effective fertilization of these after anthesis (Evans and Wardlaw, 1976). Earlier research by Hoshikawa (1961) suggested that optimum temperature for fertilization of wheat is 18° to 24°C, the minimum is 10°C and maximum 32°C.

According to Slafer and Rawson (1995), the base temperature (i.e., the maximum temperature at or below which rate of development is zero) for wheat at anthesis is 8.1°C. The production and transfer of viable pollen pollen grains to the stigma, germination of the pollen grains and growth of the pollen tubes down the style, and effective fertilization is necessary for successful seed set. All these phases are temperature sensitive. Several researchers reported that high temperature during anthesis can cause sterility in wheat crop (Saini and Aspinall, 1982; Randall and Moss, 1990; Stone and Nicolas, 1995; Wardlaw and Moncur, 1995). But, cold temperature also causes enormous agricultural losses, especially in sub-tropical and temperate grain crops (Thakur, *et. al*., 2010). Since wheat is grown as a winter crop in India its flowering and anthesis time occurs in cold weather (December-January). Prevalence of very cold weather can cause sterility as high as 98% (Subeidi and Budhathoki, 1995; Subedi *et. al*., 1996). After emergence from the flag leaf sheath, wheat ear is highly susceptible to damage by frost (Marcellos and Single, 1984). Temperature as low as freezing can severely injure wheat at its reproductive stage and greatly reduce grain yields. The following experiment was undertaken to study the effect of temperature during the anthesis period on pollen and spikelet sterility of wheat crop. The study was also aimed in understanding the differential response of aestivum and durum wheat to temperature changes.

Results and discussion

Impact on crop phenology

Results showed that days to attain different phonological stages varied from cultivar to cultivar. Under normal sowing dates (7th November) HD 2851 variety took least days to reach anthesis and maturity, while PBW 343 took maximum days (Table 2). Under late sown condition, HD 2936 required maximum number of days to attain anthesis and maturity. Phenology of wheat crop was significantly affected by temperature. Days to anthesis and days to maturity was affected by sowing time of the crop. In PBW 343, HDR 77 and HD 2936 varieties crops sown during the month of October took more time to reach the anthesis stage than crops sown in November. But days to anthesis got reduced in December and January sown crop in all the varieties. Crops sown in later dates (7th & 27th December and 7th January) reached anthesis stage earlier with lesser thermal time. PBW 343 variety flowered 30 days earlier in last sowing date with 902°C thermal time as compared to first date of sowing (1244°C thermal time). Days to maturity also followed the

Table 1. Days to anthesis and maturity of aestivum and durum varieties of wheat sown at seven different dates

DOS	Wheat variety				
	HD2851	PBW343	HDR77	HD2936	HI8498
			Days to anthesis		
7th Oct	85	101	85	104	98
21st Oct	89	109	85	107	99
7th Nov	89	102	93	99	95
25th Nov	94	98	96	98	96
7th Dec	73	82	78	79	95
27th Dec	75	83	76	82	77
7th Jan	69	71	69	72	71
LSD (P=0.05)	6	7	5	5	6
			Days to maturity		
7th Oct	139	144	142	156	140
21st Oct	135	149	137	147	142
7th Nov	123	135	126	136	132
25th Nov	112	125	117	131	122
7th Dec	100	112	103	119	122
27th Dec	98	116	113	111	104
7th Jan	97	102	99	103	100
LSD (P=0.05)	10	11	10	12	8

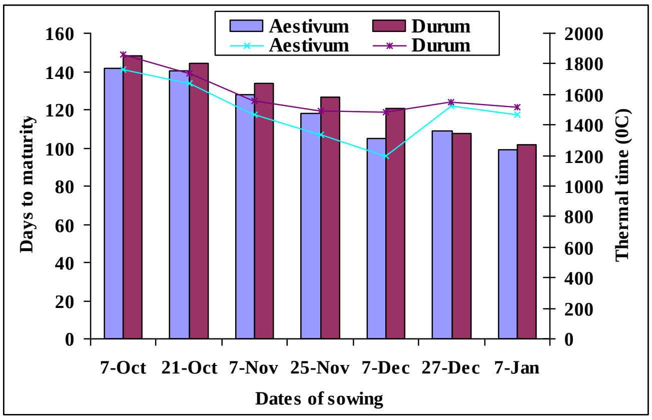

Fig 1. Crop growth duration and thermal time of aestivum and durum wheat varieties

Table 2. Correlation between temperature pollen sterility and pollen germination in wheat

Wheat variety	Correlation coefficient	
	Pollen sterility (%)	Pollen germination (%)
HD 2851	-0.96	0.88
PBW 343	0.33	0.22
HDR 77	-0.94	0.57
HD 2936	-0.50	-0.45
HI 8498	-0.95	0.60

same trend as days to anthesis. Total crop growth duration was also affected by sowing dates. Crops sown in 7th and 21st October took maximum days to mature, while last three sowing dates recorded lesser crop growth duration (Table 1). Wheat varieties varied in the number of days and thermal times required to reach maturity. In early sown wheat thermal time required to reach maturity was more than late sown condition. Crop growth duration as well as thermal time was more in durum varieties as compared to aestivum varieties. Days to maturity were 42 and 47 days earlier in January sown aestivum and durum wheat as compared to 7th October sown crop (Fig.1). Early sowing also increased thermal time in both durum and aestivum cultivars. This is due to the fact that mean temperature during the crop growth period was less in early sown wheat, which has enhanced the crop growth period. In case of late sowing mean temperature was more, this hastened both anthesis and maturity of wheat crop. Similar results were reported by Sikder (2009), who found out that for all the phenological stages wheat plants of normal sowing condition needed higher heat units than the late sowing condition. According to Subedi *et. al*., 1998, cold temperatures have been found to affect both phenology and grain filling, prolonging the time taken to complete the pre-flowering phases, with early flowering material being particularly sensitive.

Impact of temperature on pollen sterility

Temperature at the time of anthesis significantly affected fertility of the pollen grains. Wheat varieties (HD 2851 & HI

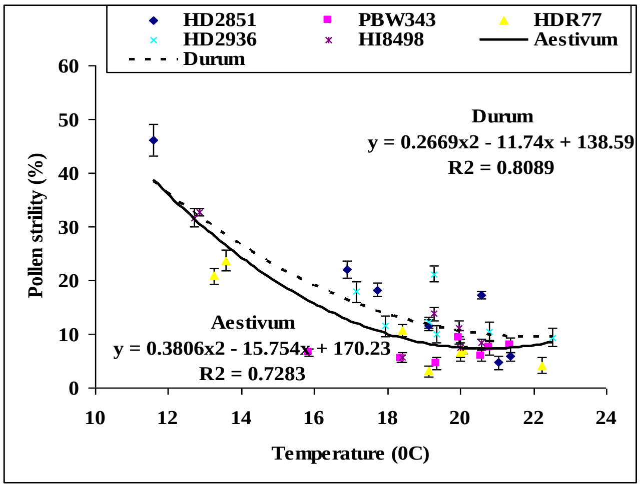

Fig 2. Impact of temperature on pollen sterility in wheat

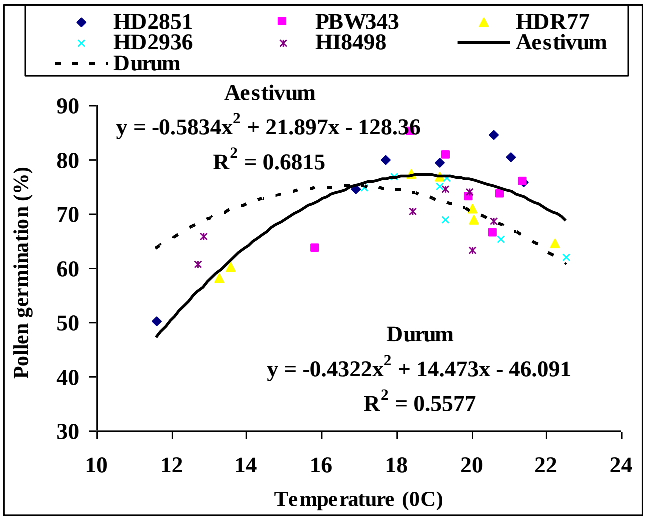

Fig 3. Impact of temperature on pollen germination percentage in wheat

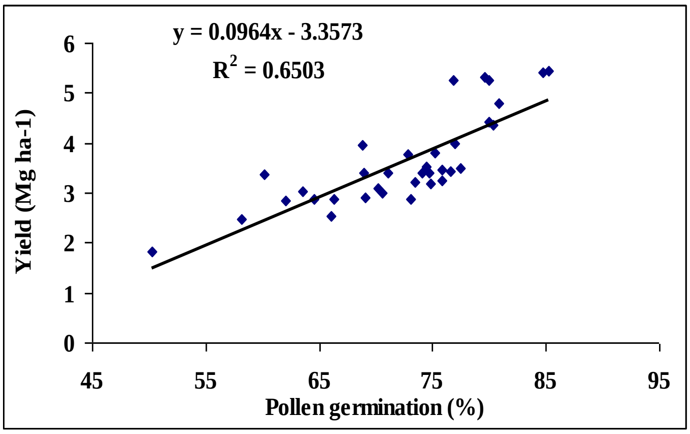

Fig 4. Relationship between pollen germination percentage and yield of wheat crop

8498) where anthesis took place earlier (Dec & Jan) showed higher pollen sterility percentage as compared to others. Maximum sterility percentage in pollen grains (46.1%) was observed in case of HD 2851 variety, which experienced very low mean temperature (11.6°C) during anthesis in the month of January (Fig. 2). Sterility percentage of pollen grains was also very high (32.8%) in HI 8498 variety when mean temperature was 12.9°C. Pollen grains were more fertile when temperature was above 15°C in both aestivum and durum varieties of wheat crop. In HDR 77 variety 23.7% of pollen grains were sterile when anthesis occurred at a mean temperature of 13.6°C. But with rise in temperature sterility percentage got reduced. Similar results were reported by Subedi *et al*., (1998) who also reported that cool temperature around heading prolonged the time to anthesis and led to greater degree of sterility in wheat cultivars. According to Subedhi and Budhathokhi, 1995, wheat crop in Nepal is a winter crop, and their flowering coincides with cold weather of January-February. Most of the cultivars suffer from sterility as high as 98% in such condition.

Impact of temperature on pollen germination

At lower temperature more number of sterile pollens led to less pollen germination on stigma. At temperature below 15°C, germination percentage of pollen grains was less in HD 2851, HI 8498 and HDR 77 variety of wheat. Lowest pollen germination (50.3%) was observed in HD 2851 variety when anthesis occurred at mean daily temperature of 11.6°C (Fig.3). The other 2 varieties of wheat (PBW 343 and HD 2936) have not experienced low temperature during anthesis, hence pollen germination was not affected by low temperature. Maximum pollen germination (85.2%) was observed in PBW 343 variety, when temperature was 18.4°C. In all the varieties pollen germination was maximum between mean temperatures of 18°-20°C. In all the varieties except PBW 343 a negative correlation between temperature and pollen sterility was observed. This shows that with decrease in temperature pollen sterility increased. Harmful effect of low temperature was maximum (r = -0.96) in HD 2851 variety of wheat (Table 2). On the other hand a positive correlation was found between temperature and pollen germination in all the varieties except HD 2936. It proved that as temperature increased pollen germination also increased. This effect was also maximum (r = 0.88) in HD 2851 variety (Table 2). Effect of temperature on pollen grains was more in HD 2851 variety, since this variety experienced very low temperature at anthesis stage of the crop. Pollen germination was found to be positively correlated with yield (R^2=0.65) of wheat crop (Fig. 4).

This shows that higher pollen germination resulted in better grain setting, resulting in more yield of wheat crop. Maximum yield (5.44 Mg ha-1) was recorded in PBW 343 variety of wheat when pollen germination was 85.2%. On the other hand lowest yield (1.81 Mg ha-1) was found in HD 2851 variety of wheat when pollen germination was 50.3%. This occurred when the variety experienced very low temperature during anthesis on the month of January. Correlation coefficient (r) between pollen germination and yield was +0.86 and +0.68 for aestivum and durum varieties respectively. Cold stress caused reduction in the number of pollens germinating hence decreasing number of pollen tubes entering the ovary.

Although wheat ovary contains a single embryo sac and one pollen tube is required for fertilization (Saini et. al., 1983), but the pistils were no pollen tube reached the ovary failed to set grains in wheat crop. Low grain set was reported in various varieties of wheat grown in the field (Couvreur and Masse, 1985; Ledent et. al., 1988; Meynard and Sebillotte, 1994). Earlier workers reported that in wheat, low grain set was recorded in field trials when the temperature at or around meiosis was low. Poor grain set is caused due to the induction of both male and female sterility. In this experiment low temperature caused sterility of pollen grains resulting in poor pollen germination, thereby reduced grain setting in wheat crop.

Materials and methods

Site

Field experiment was carried out in the year 2005-06 in Indian Agricultural Research Institute, New Delhi (28°40´N and 77°12´E) research farm with wheat as the target crop. The climate is subtropical semiarid with hot and dry summers and cold winters. Mean annual maximum temperature is 35°C while the mean minimum temperature is 18°C.

Crop management

Three aestivum (HD 2851, PBW 343, HDR 77) and two durum(HD 2936, HI 8498) wheat varieties were sown at seven different sowing dates starting from first week of October to first week of January at fortnightly interval (Table 1) in a randomized block design (RBD) . Since time of sowing varied so flowering took place at different time exposing the crops to different temperatures during anthesis.
The crops were raised following standard agronomic practices as prescribed for wheat.

Plant material

At mid flowering (anthesis) stage wheat florets were sampled in the morning and brought to the laboratory. Sampling was done for 3-4 days during this stage for all the treatments. In the laboratory florets were artificially opened by removing lemma with the help of a needle and pollens were dusted on the slide with brush from the anthers. Pollen grains were stained with 10% iodine solution on glass slide and observed under microscope. Only fertile pollens got stained with iodine, while pollens which did not get stained were sterile pollens. Slides were scored for number of stained as well as unstained pollens.

Sterility percentage of pollens was calculated from total number of pollens and number of sterile pollens. Quantification of pollen germination percentage was done by sampling wheat florets at noon time. Deposition of pollens grains on stigma were observed, under a microscope by staining it with cotton blue. Pollens were scored as germinated when pollen tube length was more than the diameter of the pollen grain. Pollen germination percentage was calculated from total number of pollens deposited and number of pollens germinated on stigma. Observations were taken in five to six randomly selected microscopic fields. Dates of flowering, anthesis and physiological maturity were recorded. Mean daily air temperature was recorded during the entire crop growth period.

Conclusions

This study showed that temperature affected both phenology and pollen sterility in wheat crop. Less temperature during the crop growth period enhanced crop duration while higher temperature hastened anthesis and maturity of crop. Low temperature during anthesis increased pollen sterility, thereby decreasing germination of pollen grains in both aestivum and durum wheat. Wheat varieties where anthesis took place in the month of December and January experienced very low temperature leading to more number of sterile pollens. Reduced pollen germination led to less yield of wheat crop.
This shows that low temperature has profound effect on wheat crop. Early sown wheat crops will be most affected where low temperature could occur during the anthesis stage. There is a need to develop better adaptation measures to reduce the harmful effect of cold stress in wheat.

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