

YIELD AND QUALITY PARAMETERS OF WHEAT GENOTYPES AS AFFECTED BY SOWING DATES AND HIGH TEMPERATURE STRESS

MAHBOOB ALI SIAL, M. AFZAL ARAIN, SHAMADAD KHANZADA
MAZHAR H. NAQVI, M. UMAR DAHOT¹ AND NISAR A. NIZAMANI

Plant Genetics Division, Nuclear Institute of Agriculture (NIA),
Tando Jam- 70060, Pakistan.

¹University of Sindh, Jamshoro-76080, Pakistan

Abstract

Twelve wheat genotypes bred at this Institute were assessed for yield and quality parameters at two levels of sowing dates i.e., normal (18th November) and late sowing (11th December). The normal temperature persisted from December to February after which there was consistent rise in the temperature with heat shocks of 35°C in the end of March. With delayed planting, the development of plant organs and transfer from source to sink were remarkably affected, which was reflected by overall shortening of plant height, reduction in number of internodes, days to heading, days to maturity and grain filling period and ultimately in the reduction of yield and yield components. The protein content of the genotypes was higher in late condition, possibly due to low grain weight. Genotypic responses were almost similar and in the same direction, however, the intensity varied.

Introduction

Wheat (*Triticum aestivum* L.) is an important food crop cultivated over an area of about 8 million hectares with an annual production of nearly 20 million tonnes in Pakistan. It provides more than 50% of the total calories and 60% of the total protein consumed by the population as a whole. To feed the ever-increasing population in the country, the need for more wheat will continue. There are enough possibilities to increase wheat yields in Pakistan through developing new high yielding varieties and by adoption of proper package of technology (Sial *et al.*, 2000; Arain *et al.*, 2002). Yield is the function of many components which when modified have direct influence on the productivity. For instance, higher grain yields in wheat have been obtained by early sowing (Darwinkel *et al.*, 1977; Arain *et al.*, 1999; 2001; Sial *et al.*, 2000; 2001).

Temperatures above normal alter plant functions and productivity. Short heat stresses ($\geq 35^{\circ}\text{C}$) in the post-anthesis period can significantly reduce grain weight in wheat and barley (Wardlaw & Wrigley, 1994), decrease grain quality (Randall & Moss, 1990; Savin *et al.*, 1996). Stephens & Lyons (1998) suggested that the sowing dates in terms of changed temperatures are critical for determining appropriate crop yields. The present study was conducted to determine the effects of time of sowing and heat shocks during grain filling on different yield, yield components and quality traits of new wheat cultivars.

Materials and Methods

Ten advanced wheat (*Triticum aestivum* L.) genotypes viz., SD-4085/3, SD-4047, SD-66, SD-1200/11, SD-1200/19/1, SD-1200/51, 7-03, 15-10, RWM-9313, ESW-9525 alongwith two check cultivars viz., Kiran 95 and Sarsabz were sown at two sowing dates

viz., 18 November (normal) and 11 December (late) during the year 1999-2000 at the Experimental Farm of Nuclear Institute of Agriculture (NIA), Tando Jam, Pakistan. The experiments were conducted in four replicates in randomized complete block design (RCBD) with six rows, 5m long and 30 cm inter-row spacing. The seeding rate was 100 kg/ha at each sowing date and the soil was clay loam with a pH of 7.4. Daily minimum and maximum temperatures (meteorological data) were recorded throughout the season.

The traits measured on plot basis at each sowing date were: (i) days to heading, (ii) days to maturity, (iii) grain filling period. Besides, five random plants from each genotype were selected for agronomic studies i.e., plant height, number of internodes per plant, spike length, number of spikelets per spike, number of kernels in a spike, main spike yield (g), grain yield per plot ($6m^2$). The quality characters examined were; 100 grain weight (g), protein (%), and lysine content (%). Means were compared using Duncan's Multiple Range Test (DMRT) and student's t statistic.

Results and Discussion

High temperatures beyond 35^0C persisted in October and first week of November. The temperatures became favourable by the beginning of December and continued (below 30^0C) up to 3rd week of February (occurring at 15 days after anthesis). Moderately high temperatures (27^0C - 32^0C) were recorded during 4th week of February. The linear increase in temperature continued in the month of March and by the end it reached to about 39^0C . Disastrous temperature to wheat crop ($>40^0C$) happened to be in the month of April. Overall, high temperatures in the range of 31^0C to 45^0C prevailed from 3rd week of March to second week of April (Table 1).

Mean values of different traits were compared under normal and late planting using t-statistic. Except protein content, there was decline in the mean values under late planting. This decline was significant for days to heading, days to maturity, grain filling period, plant height, spikelets per spike, grains per spike and grain yield (Table 2). There was an overall decline in grain yield of 635 kg/ha under late planting, a yield loss of 26 kg/ha per day over the normal harvest of 2902 kg/ha. The reduction in yield may be more severe, when planting is still delayed as reported by Arain *et al.*, (1999), where the intensity of yield depression was found to the extent of 38 kg/ha/day. Studies have shown that moderately high temperatures (25 - 32^0C) and short periods of very high temperatures (33 - 40^0C and above) during grain filling severely affect the yield, yield components and grain quality in wheat and barley (Chowdhry & Wardlaw, 1978, Wardlaw *et al.*, 1989, Stone & Nicolas, 1994, Reynolds *et al.*, 2001).

The response of genotypes to sowing dates varied for different yield contributing characters studied. The number of days required for heading under normal sowing ranged between 68 and 90. This span was reduced to 80 days (upper limit) under late planting. This reduction was more pronounced in the genotypes which required higher number of days for heading under normal planting. The phenomenon is almost universal as time to heading shortens, in a curvilinear fashion as temperature increases (Tashiro & Wardlaw, 1999; Slafer & Whitechurch, 2001). Similarly, the genotypes matured 4 to 10 days earlier when planted late, indicating forced maturity due to high temperatures. The transfer of assimilates from source to sink, determines the grain filling period. When the genotypes were provided the optimum conditions (normal), the grain filling period was higher (42 to 55.5 days) than under stress of late planting (42 to 49 days). At least one genotype, Kiran 95 was identified which possessed inherent earliness for heading and maturity under normal and late planting and seems to have tolerance capability to high temperature (Table 3a).

Table 2. Comparison of agronomic and quality traits of wheat genotypes under normal and late sowing using mean standard error and t-value.

Characters	Mean values \pm standard error		t-value
	Normal sown	Late sown	
Days to heading	80.33 \pm 2.15	76.48 \pm 0.89	2.94 *
Days to maturity	128.37 \pm 1.12	121.72 \pm 0.57	7.36 *
Grain filling period	48.02 \pm 1.49	45.21 \pm 0.54	2.21 *
Plant height (cm)	103.60 \pm 1.77	92.77 \pm 1.66	6.49 ***
Spike length (cm)	12.18 \pm 0.39	11.91 \pm 0.42	0.47 n.s
Spikelets per spike	22.62 \pm 0.79	20.64 \pm 0.45	3.01 *
No. of grains per spike	60.94 \pm 2.18	53.33 \pm 1.58	3.88 **
No. of internodes per plant	3.95 \pm 0.09	3.90 \pm 0.05	0.50 n.s
Spike yield (g)	2.04 \pm 0.11	2.10 \pm 0.07	-0.55 n.s
100 grain wt. (g)	4.35 \pm 0.10	4.21 \pm 0.10	1.75 n.s
Grain yield (kg/plot)	1.74 \pm 0.04	1.37 \pm 0.05	8.05 ***
Protein (%)	10.01 \pm 0.21	10.37 \pm 0.18	-4.23 **
Lysine content (%)	3.06 \pm <.01	3.06 \pm <.01	-0.27 n.s
Grain yield (kg/ha)	2902 \pm 60.0	2287 \pm 78.0	8.05 ***

Under favourable temperatures, the genotypes which were relatively late in heading possessed better vegetative growth, reflected by increased plant height and more number of internodes. The yield components such as spike length, number of spikelets per spike and number of grains per spike were also found associated with the vegetative growth period (Table 3b). The development rate of plant organs is generally accelerated due to increased temperatures. The late planting reduced plant height in all the genotypes, the maximum to the extent of 19.5 cm in genotype SD-1200/11. The spike length, number of spikelets per spike and number of grains per spike were also reduced under late planting in almost all the genotypes, except SD-4085/3, where there was a substantial increase for these characters. When growth resources are limited by heat stress, the size of plant organs such as leaves, tillers and spikes are reported to be reduced (Fischer, 1984).

Yield of a genotype is the most integrative trait, because it is influenced by all known and unknown factors (Araus *et al.*, 2001). The genotypes produced higher grain yield, when planted on 18th November as compared to the 11th December. Genotypes 7-03, SD-4085/3, ESW-9525, SD-4047 and SD-1200/51 were promising in yield in November sowing, while genotypes RWM-9313 and SD-4047 produced higher grain yield than other entries under late planting. The phenomenon of yield depression due to late planting was also computed in each genotype. As high as 33% and 31% yield reduction was observed in genotypes SD-1200/11 and SD-1200/51, respectively (Table 3c). The genotype RWM-9313 did not show any remarkable reduction in yield, when planted late and seems to possess tolerance to high temperature to some extent. The other genotype having less yield depression was SD-4047 (12%). Higher yields from early sown wheat crop is almost universal (Darwinkel *et al.*, 1977; Arain *et al.*, 1999).

Taking quality parameters into consideration, it was observed that percent protein was significantly influenced by changing planting time; whereas, 100 grain weight (g) and lysine content (%) did not show any significant effects of sowing time (Table 3d).

Protein percent was significantly higher in late sown wheat grains as compared to early (normal) sown, as heat shock proteins are synthesized at very high rates under high

temperature stress and are believed to have a protective role under environmental stress (Reynolds *et al.*, 2001). Since, there was a decline in the overall grain yield under late planting, therefore, it is obvious that higher temperatures have been the main cause of higher protein content in the late sown wheat crops. Earlier studies have also shown a negative correlation between grain yield and protein content (Randall & Moss, 1990). The local check variety Kiran-95 had the highest 100-grain weight and Sarsabz gave significantly higher protein and lysine contents at normal sowing date (Table 3d); whereas, at late sowing SD-66, SD1200/51, SD1200/19/1 had high 100-grain weight, protein and lysine contents. Kiran 95 had also higher protein % at late sowing (Table 3d).

Our studies support the use of early seeding dates for obtaining maximum yield. However, the wheat yields in warm environments can be raised significantly by modifying agronomic practices, such as adding farm yard manure to improve soil physical and chemical conditions and to increase the conservation of soil moisture (Reynolds *et al.*, 2001).

References

Arain, M.A., M. Ahmad and M.A. Rajput. 1999. Evaluation of wheat genotypes under varying environments induced through changing sowing dates. *Proc. Symp. New Genetical Approaches to Crop Improvement-III*. Nuclear Institute of Agriculture, Tando Jam, Pakistan, pp.163-173.

Arain, M.A., M.A. Sial and M.A. Javed. 2001. Stability analysis of wheat genotypes tested in multi- environmental trials (METs) in Sindh Province. *Pak. J. Bot.* 33: (special issue): 761-765.

Arain, M.A., M.A. Sial and M.A. Javed. 2002. Influence of different seeding rates and row spacings on yield contributing traits in wheat. *Pak. J. Seed Tech.*, 1: 01-6.

Araus, J.L., J. Casadesus and J. Bort. 2001. Recent tools for the screening of physiological traits determining yield. In: *Application of Physiology in Wheat Breeding*. (Eds.): M.P. Reynolds, J.I. Ortiz- Monasterio and A. Mc. Nab. Mexico, D.F.: CIMMYT, pp. 59-77.

Chowdhry, S.I. and I.F. Wardlaw. 1978. The effect of temperature on kernel development in cereals. *Aust. J. Agric. Res.*, 29: 205-223.

Darwinkel, A., B.A. Ten Haq and J. Kuizenga. 1977. Effect of sowing date and seed rate on crop development and grain production of winter wheat. *Neth. J. Agric. Sci.*, 25: 83-84.

Fischer, R.A. 1984. Physiological limitations to producing wheat in semi-tropical and tropical environments and possible selection criteria. In: *Wheats for More Tropical Environments. A Proceedings of the International Symposium*, Mexico, D.F.: CIMMYT, pp. 209-230.

Randall, P.J. and H.J. Moss. 1990. Some effects of temperature regime during grain filling on wheat quality. *Aust. J. Agric. Res.*, 41: 603-617.

Reynolds, M.P., S. Nagarajan, M.A. Razzaque and O.A.A. Ageeb. 2001. Heat tolerance. In: *Application of Physiology in Wheat Breeding*. (Eds.): M.P. Reynolds, J.I. Ortiz- Monasterio and A. Mc. Nab. Mexico, D.F.: CIMMYT, pp. 124-135.

Savin, R., P.J. Stone and M.E. Nicolas. 1996. Response of grain growth and malting quality of barley to short periods of high temperature in field studies using portable chambers. *Aust. J. Agric. Res.*, 47: 465-477.

Sial, M.A., M.A. Arain and M. Ahmad. 2000. Genotype x environment interaction on bread wheat grown over multiple sites and years in Pakistan. *Pak. J. Bot.*, 32: 85-91.

Sial, M.A., M.A. Arain, M.A. Javed and M.A. Rajput. 2001. Genotype-environment interaction for grain yield in bread wheat. *Proceedings of Pakistan Academy of Plant Sciences*, 38(1): 41-46.

Slafer, G.A. and E.M. Whitechurch. 2001. Manipulating wheat development to improve adaptation. In: *Application of Physiology in Wheat Breeding*. (Eds.): M.P. Reynolds, J.I. Ortiz-Monasterio and A. Mc. Nab. Mexico, D.F.: CIMMYT, pp. 160-170.

Stone, P.J., and M.E. Nicolas. 1994. Wheat cultivars vary widely in their responses of grain yield and quality to short periods of post anthesis stress. *Aust. J. Plant Physiol.*, 21: 887-900.

Tashiro, T. and I.F. Wardlaw. 1999. The response to high temperature shock and humidity changes prior to and during the early stages of grain development in wheat. *Aust. J. Plant Physiol.*, 17: 551-561.

Wardlaw, I.F. and C.W. Wrigley. 1994. Heat tolerance in temperate cereals. An overview. *Aust. J. Plant Physiol.*, 21: 695-703.

(Received for publication 27 July 2003)