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Grain filling duration as a means for increasing yield in spring wheat

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Abstract

Grain filling duration, the period between heading date and physiological maturity, plays an important role in determining the final grain yield in spring wheat. The variability for grain filling duration and selected agronomic traits was studied in 72 spring wheat genotypes. There was wide genetic variation in the genotypes for the traits examined. It was observed that earlier heading lines tended to have longer grain filling duration as compared to later heading genotypes. Genotypes having shorter grain filling duration were identified for further utilization. The grain filling duration was significantly correlated with grain yield and its components, kernels per spike and kernel mass. The results suggest that increasing grain yield in spring wheat was possible through breeding for grain filling parameters.

Key words: Spring wheat, *Triticum aestivum*, grain filling

Introduction

The grain filling duration is the most important phase in the wheat (*Triticum aestivum* L. emend Fiori & Paol.) plant's life cycle as it is responsible for producing healthy and well-filled kernels that lead to total harvested grain yield. In the present scenario of environmental changes which are leading to squeezing of the duration of the cold season, the grain filling period in wheat is greatly affected by the prevailing temperature conditions. It has been observed that any changes in day and night temperature or early onset of desiccating winds at the time of grain filling becomes a limiting factor affecting grain yield to a great extent through reduction in kernel mass. It is also worth mentioning that grain yield in spring wheat is closely associated with variation in temperature [1]. Wheat production, particularly in India, is a gamble with temperature. This fact becomes evident from the varying yield levels recorded from various wheat producing zones in India.

Grain yield in wheat is mainly contributed by three yield components, *viz.* tillers per unit area, kernels per spike and kernel mass (weight). Kernel mass is determined by grain filling duration and grain filling rate of the photo-assimilates. Grain filling duration in wheat is regarded as the period between heading to physiological maturity of the spikes. The duration of grain filling, rather than the rate of grain filling, has been regarded as an important determinant of grain yield [2, 3]. The converse opinion, that grain filling rate rather than grain filling period is closely associated with grain yield, has also been reported [4, 5]. Terminal heat stress caused by early onset of hot desiccating winds at the time of maturity of wheat necessitates development of varieties having shorter grain filling duration (with co-existing faster grain filling rate) for reducing losses in grain yield. Grain filling duration is also very important in breeding cultivars suitable for fitting into various crop rotations. The present study was conducted to screen germplasm lines for variation in grain filling duration and study its relationship with other agronomic traits for being utilized in breeding programmes.

Materials and methods

Seventy-two spring wheat germplasm lines, which included cultivars and strains, belonging to early, medium and late maturity groups were utilized to study their grain filling behaviour. The material was grown in 3 row plots of 3m length, spaced 23cm apart, in two replications. The middle row of the plots was used for recording data on days to heading, days to physiological maturity, plant height at maturity (cm), biological yield (g), grain yield per metre row (g), harvest index (%), spike length (cm), kernels per spike and 100-kernel

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mass (g). Days to heading was recorded as the number of days after sowing when 50% of the spikes in a plot were completely emerged from the flag leaf sheath. Days to physiological maturity was estimated as the number of days after sowing till the glumes lose completely their green colour in 75% of the plot. The grain filling duration was estimated as the difference between days to physiological maturity and days to heading. The yield attributing traits were recorded from 10 individual plants and their means were utilized in statistical testing.

The germplasm lines used in this study formed part of the working collection. These lines were screened for their flowering characteristics over a number of years and they showed very little variation as far as their heading and other morphological attributes were concerned. All care was taken to raise a good crop and minimize any variation due to environmental and cultural conditions. In the present study, pooling of two years data was done so as to eliminate or minimize any variation in heading and other characteristics. Pooling of data recorded over years also enhances the accuracy and efficiency of the estimates. The pooled data of two years were statistically analyzed. Broad sense heritability was calculated following Fehr [6] and correlation coefficients were computed among yield traits and grain filling duration following Johnson *et al.* [7].

Results and discussion

There was a wide range of variability in the material as revealed by the range for various yield and related characters observed in the present study (Table 1). The vegetative period in the material screened in the present study ranged from 62 to 81 days. The grain filling duration of the reproductive phase varied from 36 to 55 days. It was observed that the grain filling duration in early heading lines (62-65d) ranged from 44 to 47 days, while in the later heading lines (75-81d), it ranged from 41 to 46 days. Two genotypes were found to exhibit marked variation for grain filling duration. 'KS-13' was the genotype with shortest grain filling duration of 36 days with a vegetative phase of 73 days, while 'E-401' had the longest grain filling duration of 55 days with 67 days vegetative period. The germplasm material screened revealed that early heading lines tended to have longer grain filling duration as compared to later heading genotypes.

The heritability values (Table 1) were high for plant height, heading, physiological maturity, spike length, grain filling, kernels per spike, 100-kernel mass and were intermediate for grain yield, harvest index and biological yield. Grain yield was positively correlated with grain filling duration, spike length, kernels per spike, kernel mass and biological yield (Table 2). But it was negatively correlated with harvest index. Such negative correlation of grain yield with harvest index is an indication that selection based only on harvest index would not lead to segregants having higher grain yield; further it also suggests that the material screened in this study possessed higher biomass/foliage. Among the yield components, spike length was significantly correlated with kernels per spike, biological yield and grain yield; while kernels per spike was significantly correlated with both biological and grain yield. The grain filling duration was observed to be significantly correlated with its components, the number of kernels per spike and 100-kernel mass, as well as with biological yield and grain yield (Table 2).

Table 1. Range, mean and heritability estimate for 10 characters in spring wheat

Character	Range	Mean	h^2
Heading (d)	62-81	70.0	0.95
Physiological maturity (d)	105-124	104.0	0.94
Grain filling (d)	36-55	43.0	0.88
Plant height (cm)	69.5-136.5	86.7	0.97
Spike length (cm)	8.6-13.0	10.7	0.89
Kernels per spike	34-84	49.0	0.84
100-kernel mass (g)	3.1-5.9	4.1	0.82
Biological yield (g)	153-405	253.0	0.53
Grain yield per m row (g)	61-121	89.5	0.58
Harvest index (%)	24.7-50.0	35.9	0.63

Increasing yield *per se* has been and shall always be the prime goal of breeders. In wheat, where improvement in yield has been a subject of intense selection pressure, any further gains in yield enhancement has to come through manipulation of crop traits attributing to high grain yield. The traits which have been consistently modified during the process of breeding can be used as selection criterion for further increasing yield potential [8]. The grain filling duration in wheat is one trait which can be used as a selection criterion as it greatly affects productivity and production.

Good genetic variation was observed in the material screened for all the characters that were studied

Table 2. Phenotypic correlation coefficients between grain filling duration and selected agronomic traits in spring wheat

Traits	Spike length	Kernels/spike	Kernel mass	Biological yield	Harvest index	Grain yield
Grain filling duration	0.08	0.24*	0.28*	0.25*	0.05	0.45**
Spike length		0.62**	0.08	0.51**	-0.18	0.73**
Kernels per spike			0.03	0.40**	0.08	0.57**
Kernel mass				0.10	0.16	0.34*
Biological yield					-0.82**	0.78**
Harvest index						-0.25*

*, ** Significant at P = 0.05 and 0.01, respectively

which shows that they were utilizable for the specific traits required in the development of cultivars. The vegetative phase accounted for a major portion (62 to 81 days) of the total crop duration (105 to 124 days) and in fact it determines the quantum of harvested grain yield. Therefore, the duration of vegetative phase is equally important as the grain filling duration for determining grain yield in wheat [9]. The period before anthesis has been largely recognized as being critical for grain yield [8].

It was observed that early heading lines tended to have longer grain filling duration as compared to later heading genotypes. The early lines, by having a prolonged or more favourable grain filling period, were thus able to accumulate more photosynthates which was reflected through their higher kernel mass. On the other hand, the late heading genotypes, generally getting lesser time for grain filling, were at risk to exposure/influence by environmental factors, particularly temperature, during grain filling period. It has been suggested that short grain filling duration in some late heading genotypes also contributed to stress tolerance [1]. Thus, the short grain filling duration of germplasm line 'KS-13', screened in this study, gives an opportunity for its further exploitation by introducing shorter grain filling duration in late genotypes and also as a likely source for incorporating stress tolerance in late heading genotypes.

The grain filling duration has a great bearing on kernel weight, which is related to kernel size. According to Grafius [10], the maximum kernel size is determined by the size of lemma and palea of the spikelets. Similarly, Miller [11] observed a positive correlation between kernel weight and volume of the floral cavity. Hence, it can be deduced from the above statements that spikes bearing lemma and palea of larger size would produce grains of higher mass. But, in fact, the actual kernel size and weight is determined by competition for resources and environmental factors. This fact can be corroborated by referring to the 'Buitre' lines developed from CIMMYT, Mexico, which have very long spikes but produce shriveled grains. In the present study, spike length showed significant correlation (r = 0.62) with kernel number per spike, but it had no significant correlation with 100-kernel mass (Table 2). This means that genotypes with longer spikes may not necessarily produce bold kernels. The potential kernel weight is mostly dependent on genotype, but it may be limited to some extent by post-anthesis assimilate supply. It is known that after the grain number in the spike becomes fixed, kernel mass has a major influence on the final grain yield in wheat. Kernel mass is dependent on the duration and rate of grain filling. An extended grain filling duration would increase the availability of photo-assimilates leading to higher grain yield. However, grain filling rate, being more affected by environmental factors like high temperature during grain filling period, causes reduction in kernel weight by reducing the grain filling duration [12].

The correlations among yield traits and grain filling duration (Table 2) revealed that grain yield had significant positive correlation with the major yield components, spike length, kernels per spike and 100-kernel mass. Improvement in yield is thus possible through improvement in these yield component traits. Grain filling duration showed significant positive correlation with kernels per spike and 100-kernel mass along with grain yield (Table 2). The kernels per spike and 100-kernel mass also reveal the total grain filling capacity (sink capacity) of the wheat plant. A positive correlation of these two yield traits with grain filling duration reflects its importance with respect to the final grain yield. This observation opens up the avenue that breeding for higher grain yield is possible via breeding for grain filling parameters.

The significant correlation of grain yield with grain filling duration was reflected through the effect of the length of grain filling duration on the number of kernels per spike and kernel mass (Table 2). A corollary of this observation is that, any increase in the grain filling duration would increase grain yield provided the resultant late maturity of the genotype does not make it susceptible to terminal heat stress which may affect the grain mass. The above observations in the present study are in agreement with the results of Gebenyehou et al. [13]. In general, there is agreement that the higher the temperature the shorter the grain filling period. Manipulation of temperature response in genotypes is, thus, essential for increasing the grain filling duration to obtain higher grain yield.

It has been observed that a faster grain filling rate is required in late heading genotypes, particularly in areas experiencing heat stress at the time of heading and grain filling. The high association between grain filling rate and kernel weight [1], shows that simultaneous selection for grain filling rate is possible through selection for kernel weight.

A breeding strategy involving selection for early heading (longer grain filling duration) in early segregating generations followed by selection for grain yield and grain filling duration in later generations utilizing multilocation replicated testing can be followed. The utilization of genetic variation, like 'KS-13' screened in this study, would be very beneficial in manipulation of grain filling duration for obtaining higher yielding genotypes.

Focus on exploiting grain filling duration for yield improvement would be a pragmatic approach in areas experiencing warmer conditions during grain filling.

References

1. **Bruckner P. L. and Frohberg R. C.** 1987. Rate and duration of grain fill in spring wheat. Crop Sci., **27:** 451-455.
2. **Spiertz J. H. S., Tennhag B. A. and Kupers L. J. P.** 1971. Relation between green area duration and grain yield in some varieties of spring wheat. Netherlands J. Agril. Sci., **9:** 211-222.
3. **Evans L. T., Wardlaw I. F. and Fischer R. A.** 1975. Wheat. *In*: L.T. Evans (ed), Crop physiology: some case histories. Cambridge Univ. Press, Cambridge, pp. 101-149.
4. **Nass H. G. and Reiser B.** 1975. Grain filling and grain yield relationships in spring wheat. Can. J. Plant Sci., **55:** 673-678.
5. **Sayed H. I. and Gadallah A. M.** 1983. Variation in dry matter and grain filling characteristics in wheat cultivars. Field Crops Res., **7:** 61-71.
6. **Fehr W. R.** 1987. Principles of Cultivar Development, Vol.1, Theory and Technique. Macmillan, New York.
7. **Johnson H.W., Robinson H. F. and Comstock R. E.** 1955. Genotypic and phenotypic correlations in soybean and their implications in selection. Agron. J., **47:** 477-483.
8. **Slafer G. A., Calderini D. F. and Miralles D. J.** 1996. Yield components and compensation in wheat: opportunities for further increasing yield potential. *In*: M. P. Reynolds, S. Rajaram and A. McNab (eds) Increasing yield potential in wheat: breaking the yield barriers. CIMMYT, Mexico D. F. pp. 101-133.
9. **Bingham J. 1969**. The physiological determinants of grain yield in cereals. Agric. Prog., **44:** 30-42.
10. **Grafius J. E.** 1978. Multiple characters and correlated response. Crop Sci., **18:** 931-934.
11. **Miller E.** 1986. Relationships between grain weight and size of floret cavity in the wheat spike. Ann. Bot., **58:** 417-423.
12. **Wigand C. L. and Cuellar J. A.** 1981. Duration of grain filling and kernel weight as affected by temperature. Crop Sci., **21:** 95-101.
13. **Gebenyehou G., Knott D. R. and Baker R. J.** 1982. Relationships among durations of vegetative and grain filling phases, yield components and grain yield in durum wheat cultivars. Crop Sci., **22:** 287-290.