Grain yield improvement through increased assimilates and efficient partitioning of photosynthetes in Bread Wheat (*Triticum aestivum* L.)

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ABSTRACT

Wheat is one of the most important cereal crop grown throughout the world. India now ranks second in terms of total wheat production in the world and for the last 9-10 years the total wheat production in the country has stagnated. One of the ways to break this yield plateau is to develop physiologically and morphologically efficient plant types that will have more photosynthate and better sink capacity. Wheat genotypes based on the long spike buitre germplasm are characterized by visually impressive sink and source capacity. Attempts have been made during the last two decades to exploit this genetic resource through further hybridisation with advance lines. Many physiological disorders have been cited as major constraints in improving grain yield utilizing these genotypes. In view of this, an investigation was carried out to assess the intra-spike assimilate variability in selected long spike genotypes to provide genetic and physiological explanations for poor grain filling & development. Extent of genetic variability in distribution of assimilate within the spike was estimated. The increase in number of grains in spike was associated with reduction in individual grain weight in general, which was more conspicuous in distal part of the spike. This may be due to the competition for assimilates or poor translocation efficiency as the genotypes with more biomass accumulation were found to support better grain growth even at distal part of the spike. In the present paper, it has been demonstrated that increased biomass achieved by agronomic practices or genetic manipulations may enable long spike genotypes to yield more grains with desired grain size and weight, thereby increasing the per-unit productivity and production of wheat.

INTRODUCTION

India is a privileged country to attain and maintain the status of second largest producer of wheat in the world. Despite the last few years of adverse climatic conditions like drought and terminal heat stress, the total annual wheat production has been maintained at approximately 72 MT. A challenge to the wheat scientists is to increase production. Moreover, there is a need to have acceptable yield levels from two mega wheat-growing areas of India that might come under heat stress. Therefore, development of modern genotypes suitable for intensive agriculture is a prime concern. It is essential that the productivity factor be improved and steps taken to reverse the deteriorating soil health, nutrient deficiencies, and falling C/N ratio. In this direction, the winter x spring wheat hybridization, interspecific/wide hybridization for introgressing useful genes from related wheat species may be highly effective. In addition, other unexploited germplasm such as buitre germplasm for grain number and spike size, synthetic hexaploids for thousand kernel weight along with resistance to major diseases and tolerance to various types of stresses and high yield potential may also be utilized, as these unexploited materials have shown promise in Indian wheat improvement programme. CIMMYT, Mexico developed a large number of buitre based long spike wheat genotypes by persistent genetic manipulation and countless recombinations (Rajaram and Ginkel 1996). These genotypes are yet to make headway in enhancing yield. But it appears that these have good variability for a number of yield determinants and thus a good scope for recombination breeding. Varietal improvement has so far been successful in improving productivity and disease resistance. Now we need to emphasize more on increasing biomass, assessing variability in intra-spike assimilates within the spike and to increase the number of grains in spike by maintaining grain size to augment yield contributing traits in future wheat cultivars. An attempt was made to understand intra-spike distribution of assimilates in selected long spike buitre wheat genotypes for their use in wheat improvement programmes aimed at enhancing wheat yields further.

MATERIALS AND METHODS

The experimental material comprising 13 buitre type genotypes obtained from CIMMYT, Mexico was used for present study. In addition, two Indian released varieties namely HD 2329 (Bread wheat) and PDW 215 (Durum wheat) were also included as checks to make comparison. The accession number along with their pedigree details of all these genotypes and also check varieties are presented in Table 1. 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. The sowing of experimental material was done in time (around 10th November) to avoid heat stress due to rise in temperature at physiological maturity stage. Besides, the compact block was used to avoid soil heterogeneity effects and recommended agronomic practices for timely sown crop were followed to avoid moisture and other stresses so as to ensure proper expression of different traits. Observations on plant, spike, grain and other attributes were recorded at appropriate crop stage. At physiological maturity, 10 randomly selected individual plants from each genotype were harvested for analysing yield determinants. From selected plants, each spike from main shoot was cut into three equal (distal, central and basal) parts and grains from each part were carefully separated by hand threshing. The total number of grains and also the grain weight were recorded for each part separately. Besides, spike length (SPLN), and ratio between main shoot total stem dry weight (STWT) and grain weight (GRWT) were also estimated. Analysis of variance and other statistical parameters were estimated following Panse and Sukhatme (1967). The genotypes were compared for different attributes by estimating critical difference for each attribute.

Table 1: Pedigree and accession numbers of the genotypes used for the study.

Genotype #	Accession #	Pedigree details
1.	867	MS Song
2.	943	CMH79A.1380
3.	949	CMH81.749
4.	951	CMH81A.749
5.	952	CMH81A.749
6.	954	CMH79A.1384/4/AGA…
7.	957	CMH82A.1294
8.	958	CMH82A.1350
9.	961	CMH83.2517
10.	962	CMH83.2517
11.	965	CMH79A.955/CMH74.487…
12.	975	IA/IGA42//2*CMH79.487…
13.	1145	68112/WARD//Ae.sq…
14.	HD 2329 ©	HD 1962/E4870/K65….
15.	PDW215 ©	DL 5013/DWL 5002

RESULTS AND DISCUSSION

The extent of genetic variability observed among the test entries and checks revealed significant differences for all the traits recorded in this study. The spike length ranged from 8.7 cm to 20.7 cm thereby showing large variation in the material selected for the spike attributes. Genotypes # 9, #7, #2, #3 and #5 had spike length more than 19.0 cm, compared to the length of spikes in genotype #1 and local durum check of approximately 9.0 cm only (Table 2). Similarly, among the genotypes good variation was exhibited for weight of main shoot spike that ranged from 4.35 g to 68 g. Spike weight was relatively high in genotypes #9, #7, #5 and #2, whereas, genotype #8 and #11 had lowest spike weight. The genetic variation was also high for number of spikelets per spike that ranged from 19 to 26. All the lines had more than 23 spikelets per spike except genotype # 13 and 15. Genotypes # 4 and # 9 had maximum number of spikelets (26). In general, the distribution of grains within the spike was more or less uniform except that the distal portion as expected had fewer gains than the remaining two parts of the spike. The variability exhibited by the test entries for the intra-spike distribution of grains was significant. Genotype # 9 was found to have more grains distributed almost equally through out the spike. In contrast, genotype #13 had very few grains at the distal part of the spike. This information is substantiated the suggestion that number of grains are more in the central and basal portions, and the spike sterility caused due to frost damage or any other type of injury at the at distal part of spike may not affect grain yield too much. The significant genetic variability among the test entries was also observed for intra-spike assimilates distribution. However, there was no indication of any kind of association between spike length and individual grain weight at any portion of the main shoot spike in these entries. In general, the assimilates available for grains in the middle part of the spike were comparatively more than those were available for distal grains as supported by grain weight of the distal part. This kind of trend for assimilate distribution was more conspicuous in genotype #14 and # 8. In contrast, genotype # 13 had comparatively larger amount of assimilate distribution to the distal part of spike. Data revealed that there is positive association between the amounts of assimilate available to middle portion grains and the grains at the other parts of the spike. There was significant difference in main shoot straw weight among the test entries. The maximum straw weight was recorded for genotype # 9 followed by genotype # 7, #10, #4 and #3 respectively. The lowest biomass accumulation was found in genotype # 8. From the results, it was noticed that the biomass accumulation in the main shoot had positive association with individual grain weight irrespective of the position of the grains. However, grains positioned at distal portion of the spike were probably benefited more because of genotypic efficiency to accumulate more biomass in the main shoot.

Several studies have been conducted to compare major yield components of wheat varieties released at different periods. It is evident from such reports that modern cultivars though have a greater number of grains but the individual grain weight is less as compared to their predecessors (Waddington *et al* 1986; Perry and D'Antuone 1989; and Slafer *et al* 1995). Some observations by Hucl and Baker (1987) and Calderini et al (1995), indicate compensatory process between grain number and grain weight. Therefore, the success of modern wheat breeders in consistently increasing the grain number per unit area was counterbalanced by concomitant and relatively smaller reductions in the grain weight (Slafer et al 1996). Romano (1998) reported that long spike wheats can be exploited for increasing grain number per spike. However, regular and systematic attempts are being made to improve the productivity by exploiting long spike wheat genotypes with better grain number per spike and also grain weight. This task can be achieved by minimizing the negative effects of increased grain number on grain weight.

The negative relation due to linkage between grain number and grain weight has largely been attributed to competition between grains for assimilates. However, it was reported by Slafer et al 1996 that increasing the number of grains per unit area will increase the proportion of grains with reduced weight potential. Hence, they were of the opinion that the negative relationship was not due to competition among grains. The results of present study also support this view to some extent, as there was association between grain weight at middle portion and other parts of the spike. Further, it is also clear that grains at distal part in general are placed at most disadvantageous position with limited access to assimilate. Hence, any increase in number of grains at this position might lead to decrease in individual kernel weight. However, increased availability of stem reserves, as indicated by stem biomass at maturity might support proper grain filling and thus leading to formation of plump grains even at this disadvantageous position of the spike.

The ratio of grain weight per spike to total main shoot dry weight was invariably about 50 percent higher, whereas, the estimated theoretical limit for harvest index is about 60 percent only. The findings of the present study are supported by reports of Austin *et al* 1980. Foulkes *et al* 2007 also reported that role of large stem soluble carbohydrate reserves alone for yield and stress tolerance could not be confirmed. Rajaram (2005), also reported that future wheat cultivars may bear larger spikes, larger number of grains and larger seed. Most likely the translocation efficiency alone is not the reason for poor filling of grains. Instead, the availability of assimilates is the major constraint for smaller grains at the distal part of the spike. From the results of present study it can be summarized that increasing the biomass further by manipulating the agronomic practices might enable buitre based genotypes to perform better than the contemporary high yielding genotypes.

Table 2: Variability available for different grain attributes in 15 genotypes of wheat.

Gen.#	SPLN	SPLT	Grain number			Grain weight			STWT	Ratio ST/GR
			Basal	Central	Distal	Basal	Central	Distal		
1.	8.8	24	17	21	27	1.28	1.04	1.46	2.6	0.60
2.	20.0	25	31	35	28	1.84	1074	1.30	3.0	0.62
3.	19.7	23	26	24	21	1.20	1.30	1.04	3.0	0.54
4.	16.0	26	38	37	25	1.65	1.83	1.20	3.2	0.59
5.	19.6	25	42	39	31	1.84	1.96	1.42	3.6	0.59
6.	16.3	23	31	35	31	1.35	1.13	1.08	2.4	0.60
7.	20.7	24	29	33	17	2.02	1.70	1.02	3.7	0.56
8.	15.4	25	28	28	41	1.16	1.24	0.78	1.4	0.69
9.	20.7	26	43	44	42	2.28	2.04	2.04	5.6	0.53
10.	15.6	25	30	36	28	1.62	1.38	1.24	3.4	0.55
11.	13.8	24	23	24	25	0.96	0.88	1.02	2.0	0.59
12.	17.1	25	32	30	27	1.18	1.18	0.94	2.7	0.55
13.	14.7	19	16	15	11	0.90	0.92	0.52	2.5	0.48
14.	11.6	19	21	18	13	0.52	0.48	0.24	1.5	0.46
15.	8.8	19	23	23	17	1.33	1.25	0.95	2.1	0.63
C.D.	3.1	2.7	10.5	10.2	10.5	0.47	0.46	0.35	0.8	

where SPLN = Spike length, SPLT= spikelets per spike, STWT= Stem dry weight, GRWT= Grain weight

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