

Original Research Article

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Phenological Development, Grain Growth Rate, Seedling Vigour and Yield Relationships in Wheat Cultivars under Normal Sown Irrigated Conditions

Kavita Rani^{1*}, Vikram Singh¹, V. S. Mor², M. S. Dalal¹ and Ram Niwas³¹Department of Genetics and Plant Breeding, CCSHAU, Hisar, India²Seed Science and Technology, CCSHAU, Hisar, India³Department of Mathematics Statistics, CCSHAU, Hisar, India

*Corresponding author

ABSTRACT

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In North West Plain Zone (NWPZ), where the hot, dry wind is frequent during grain filling, wheat cultivars suffer from loss of grain weight because of low grain filling rate. A field study was carried out under normal sown conditions to evaluate the phenological variation in forty wheat genotypes. Significant genotypic differences were observed for most of the traits. WH 1105, WH 1138 and HD 2967 had the highest grain yield per plant 1150.0, 1136.7 and 1103.3 g/plot respectively. The grain yield showed significant and positive correlation with number of tillers per meter, flag leaf length, flag leaf area, harvest index, grain weight per spike, 1000 grain weight and grain growth rate at 28 days. Grain growth rate (GGR) at 14 and 28 days after anthesis (DAA) showed positive correlations with grain weight per spike and thousand grain weight.

Introduction

Wheat is a self-pollinating annual plant plays a major role among the few crop species being extensively grown as staple food sources in the world. In India wheat is cultivated on 30.72mha, with a production 97.44 mt and productivity 31.72q/ha. Haryana with 11.14 mt production, 2.54 m ha area and 4.39 t/ha productivity ranks third in the country (Anonymous, 2017). World demand for wheat is estimated to 840 to 1000 million tons by 2020. The need and importance of wheat is increasing day by day due to increasing in the human population. The option for increasing wheat production by expanding area under its cultivation has already been exploited almost to its maximum. Therefore, continuous efforts

are required to develop high yielding and disease resistance wheat varieties. Thus, development of high yielding wheat cultivars has always been a major objective of wheat breeding programmes throughout the world (Bhutta, 2006). For development of high yielding varieties, the proper plant architecture and duration of plants are of paramount importance.

Grain yield in wheat is a complex trait and is the product of several contributing factors affecting it directly or indirectly. For improving any plant character through selection, first the estimation of genetic parameters must be made. The grain yield and yield components of wheat are very much affected by the genotype and the environment.

Therefore, as new cultivars are being produced by breeding, the breeders study the relationships between yield and its components.

Wheat grain yield is also limited by source or sink or both (Evans *et al.*, 1975). The results of different studies by manipulating source-sink relationships during grain filling through removing leaves or grains, and shading have shown inconsistent conclusions (Slafer and Savin, 1994; Cruz-Aguado *et al.*, 1999). This inconsistency reflects the genotype and environment interactions in the availability of assimilate for grain growth (Ma *et al.*, 1990). A better understanding of the relationship between plant development and yield may assist breeders to simultaneously improve heat tolerance and yield in wheat. The primary objective of this research was to study physiomorphological characters, rate and duration of grain filling and physiological parameters that may be related to yield, and the relationships among them for utilization as selection criteria in breeding program.

Materials and Methods

A field experiment was conducted under irrigated condition at CCSHAU, Hisar, India during winter (*Rabi*) season 2013-2014. This location typically experiences moderate drought during the pre and post-anthesis periods. The soil at the location was clay loam with a pH 7.1–8. The experimental materials comprised of genetically diverse 40 wheat genotypes whose description is given in Table.1. Out of forty genotypes, 10 genotypes were recommended for timely sown irrigated condition, 5 were recommended for late sown irrigated condition, 3 varieties for early sown conditions out of which two for rainfed conditions and one for restricted irrigation conditions and 22 advance breeding lines. Observations for all the traits were recorded on five randomly selected plants for each

genotype in each replication. The data were recorded for days to 50% heading (DH), days to anthesis (DA), plant height (PH), flag leaf length (FL), flag leaf width (FB), flag leaf area (FLA), number of tillers per meter (T), spike length (SL), main spike weight (SW), spikelets per spike (SPS), grains per spike (GPS), grains weight per spike (GW), grain length (GL), grain breadth (GB), grain growth rate (GGR) at 14, 21 and 28 days after anthesis, biological yield (BY), grain yield (GY), thousand grains weight (TGW), harvest index (HI), standard germination test (GM), seedling length (SLg), seedling dry weight (SD), vigour index-I (V-I), vigour index-II (V-II), seed density (Sd), plant straight height (SH) at 30 days, plant drooping height (Dr.H) at 30 days, field emergence index (FE) and seedling establishment (FS). Analysis of the observations recorded on different characters was carried out as per the standard procedure

Results and Discussion

All the parameters exhibited significant variability. The mean sum of squares due to genotype was highly significant for most of the character under study (Table 2).

Wheat in Haryana, experienced favorable moisture conditions along with low temperatures during vegetative stages (December–Mid February), while the reproductive stage (late February–March) experienced the moisture stress condition with high temperature (Laxman *et al.*, 2014). The optimum temperature for wheat anthesis and grain filling ranges from 12 to 22⁰C. Exposure to temperatures above this can significantly reduce grain yield (Tewolde *et al.*, 2006; Fisher, 2007). Linear increases in temperature started by the third week of February and reached approximately 25⁰C by the end of February (Fig1). Heading and maturity are important traits that are related to the adaptation of wheat cultivars under prevalent

field conditions in particular areas. Under normal environmental conditions, early heading and late maturity permits a long grain-filling period, which leads to higher grain yields in cereals (Bidinger *et al.*, 1997; Sanchez *et al.*, 2002). Post-anthesis heat stress in wheat induces several physiological effect which eventually result in smaller grain weight due to reduced grain filling period and starch synthesis duration or the combined effect of both (Hasan and Ahmed, 2005). Among 40 genotypes WH 1105, WH 1138 and HD 2967 had the highest grain yield per plant 1150.0, 1136.7 and 1103.3 g/plot respectively, under the prevailing environmental conditions of the region. These genotypes took 93.3, 95.6 and 96 days, respectively, for 50% heading and 102.3, 102.7 and 104.3 days, respectively, for anthesis. These genotypes escape late-season drought and high temperature stress.

Grain growth and development are affected by heat stress. This is because heat stress limits remobilization of photo assimilates into the developing grains (Wang *et al.*, 2012). Furthermore, heat stress can also shorten the duration of grain growth, which in turn reduces grain mass (Dias and Lidon, 2009). The genotypes WH 1105, WH 1138 and WH 1126 have moderate to high grain growth rate at 14 days (6.80, 6.53 and 7.50 g/gr/day x 10-4 respectively) with high grain yield 1150.0, 1136.7 and 1026.7 g/plot respectively (Fig.2). Genotypes attain higher test weight by maintaining higher grain growth rates under high temperature condition (Fig.3). The genotypes PBW 343, WH 1178 have high 1000-test weight (48.70g and 48.50 g resp.) with high grain growth rate at 14 days with low grain growth rate at 21 and 28 days. Wheat cultivar that can fill their grain quickly may have an advantage in environments with short, hot and dry, grain filling period. So, to avoid stress, they complete their life cycle

earlier (Whan *et al.*, 1996). However, grain yields were low when the days to 50% heading was either too short or too long viz., WH 1163 and WH 1025 with have 86.67 and 108.00 days to 50% heading with 803.3g and 886.7g/plot grain yield. This suggests that proper balancing of these developmental traits, such as pre-heading period, grain filling period and grain growth rate may facilitate a more desirable combination, which results in higher grain yield.

One of the important aspects for quality grain production is rapid emergence and good seedling establishment in the field. Therefore, quick and uniform field emergence is essential to achieve high yield in annual crops (Yari *et al.*, 2010). Seed germination and seedling growth traits are extremely important factors in determining yield (Rauf *et al.*, 2007). HD 2967 and WH 1126 have the highest vigour index-II and seedling establishment percentage (15124.43, 13477.33 and 84.00%, 82.33% respectively). These genotypes have high grain yield 1103.3g and 1026.7g per plot as well as germination percentage (95.00 and 97.67 respectively). (Likhachev, 1973) Concluded that emergence depended more on seedling vigour than on germination energy in wheat and rye. Vigour index-I was highest in WH1179 and germination percentage (98.00) with moderate seedling establishment percentage (72.00) and grain yield (903.3g/plot).

The grain yield was positively correlated with number of tillers per meter (0.866**), flag leaf length (0.815**), flag leaf area (0.689**), harvest index (0.568**), grain weight per spike (0.224**), 1000 grain weight (0.198*) and grain growth rate at 28 days (0.227*) (Table 4). Similar results found for number of effective tillers, by (Bhutto *et al.*, 2016; Kumar *et al.*, 2013) and (Nukasani *et al.*, 2013).

Fig.1 Maximum and minimum temperature at the time of grain growth period

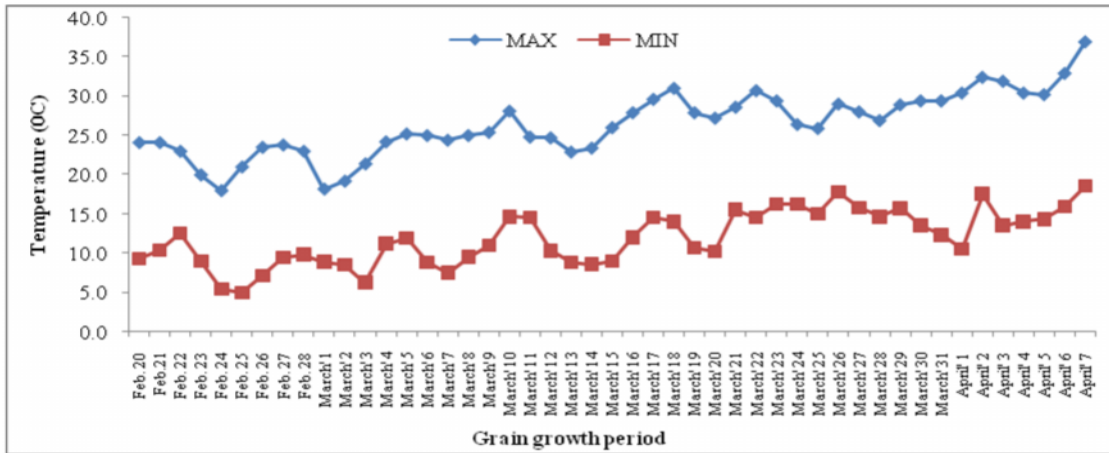


Fig.2 Mean performance of 40 genotypes w.r.t. biological and grain yield vs harvest index

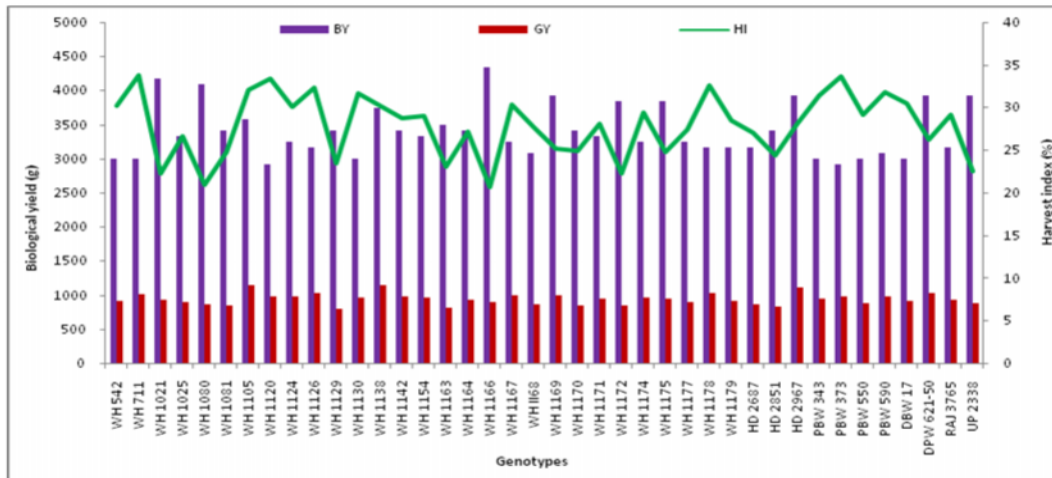


Fig.3 Graphical representation of grain growth rate vs 1000 grain weight

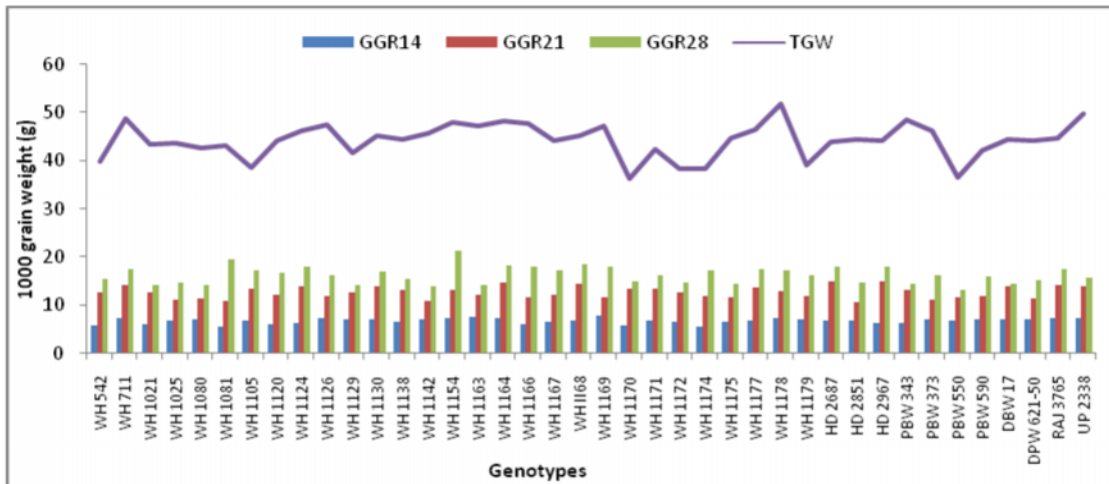


Table.1 List of genotypes along with their pedigree

Sr. No.	Genotypes	Pedigree
1	WH 542	JUPATECO/BLUEJA/URES
2	WH 711	ALD 'S'/HAU//HD2285/3/HFW-17
3	WH 1021	NYOT95(GW296)/SONAK
4	WH 1025	C591/PBW231
5	WH 1080	PRL/2*PASTOR
6	WH 1081	PBW65/2*PASTOR
7	WH 1105	MILAN/S87230//BABAX
8	WH 1120	PRL/2*PASTOR
9	WH 1124	MUNIA/CHTO//AMSEL
10	WH 1126	WBLL1*2/VIVITSI
11	WH 1129	CS/TH.CS//3*PVN/3/MIRLO/BUC/4/MILAN/5/TILHI
12	WH 1130	PRL/2*PASTOR/4/CHOIX/STAR/3/HE1*CN079
13	WH 1138	PBW65*2/PASTOR
14	WH 1142	CHEN/Ae.sq (TAUS)//FCT/3/2*WEAVER
15	WH 1154	WH337/HD2255//RAJ3077
16	WH 1163	HPW42/WH542
17	WH 1164	RL6043/4*NAC//2*PASTOR
18	WH 1166	HD29/*WEAVER/3/VEE/PJN//2*WEAVER/3/VEE/PJN//2*TUI/4/MILAN
19	WH 1167	WEAVEAR/VIVISI/3/C80.1/3*BATAVIA//2*WBLLI
20	WH 1168	ATTILA*2//CHIL/BUC*2/3/KUKUNA
21	WH 1169	KLDR/PEWITI/MILAN/DUCULA
22	WH 1170	LERKE/5/KAUZ/3/MYNA/VUL//BUC/FLK/4/MILLAN/6PROGRESOF2007
23	WH 1171	MILAN//PRL/2*PASTOR/4/CROC_1/AE.SQ(213)//PGO/3/BAV92
24	WH 1172	KLDR/PEWIT//MILAN/DUCULA
25	WH 1174	FILIN/IRENA/5/CNDOR/R143/ENIE/MEXI_2/3Ae.Sq/4/
26	WH 1175	FILIN/2*PASTOR//BERKUT/3/PASTOR/2*SITTA
27	WH 1177	HP1744/PBW443
28	WH 1178	CS//TH.86/3*PVN/3/MIRLO/BUC/4/MILAN/5/TILHI
29	WH 1179	OASIS/SKAUZ//4*BCN/3/3*PASTOR
30	HD 2687	CPAN2009/HD2329
31	HD 2851	CPAN3004/WR426//HW2007
32	HD 2967	ALD/CUC//URES/HD2160/HD2278
33	PBW 343	ND/VG9144//KAL//BB/3//YCO 'S'/4/VEE#5 'S'
34	PBW 550	WH594/RAJ3856//W485
35	PBW 590	WH594/RAJ3814//W485
36	PBW 373	ND/VG9144//KAL//BB/3//YCO 'S'/4/VEE#5 'S'
37	DBW 17	CMH79A.95/3*CN079//RAJ3777
38	DPW 621- 50	KAUZ//ALTAR84/AOS/3/MILAN/KAUZ/4/HUITES
39	RAJ 3765	HD 2402/VL639
40	UP 2338	UP368/VL421//UP262

Table.2 Analysis of variance (ANOVA) for different morpho-physiological and seed vigour traits in wheat

Source of variation	Degree of freedom	Mean Sum of Squares														
		DH	DA	PH	FL	FB	FL A	T	SL	SW	SPS	GPS	GW	GL	GB	TG W
Replications	2	0.23	0.76	0.21	1.59	0.001	5.66	2.21	0.03	0.03	1.31	6.79	0.013	0.04	0.06	4.03
Treatments	39	55.14**	50.41**	228.44**	33.01**	0.055	95.81**	985.50**	3.43*	0.19	4.95**	54.35**	0.096*	0.31	0.10	38.61**
Error	78	0.86	0.91	3.44	0.84	0.004	3.74	5.51	0.05	0.01	0.34	2.66	0.007	0.01	0.01	2.92

Source of variation	Degree of freedom	Mean Sum of Squares															
		BY	GY	HI	GG R14	GG R21	GG R28	GM	SLg	SD	V-I	V-II	Sd	SH	Dr. H	FE	FS
Replications	2	116145.83	2646.70	2.35	0.004	0.030	0.074	2.86	0.16	3.33	3307.83	151764.59	0.002	1.01	0.02	0.01	0.31
Treatments	39	426161.85**	20589.30**	40.75**	0.871	4.535**	9.397**	14.51**	2.85*	385.49**	43003.71**	4166930.53**	0.069	28.76**	22.21*	0.36	80.59**
Error	78	39222.76	2035.30	1.81	0.029	0.094	0.081	2.54	0.15	3.58	2349.39	72077.01	0.003	0.36	0.25	0.03	4.10

Table.3 Phenotypic correlation coefficients among different physio-morphological traits of wheat

	DH	DA	PH	FL	FB	FLA	T	SL	SW	SPS	GPS	GW	GL	GB	TGW	BY	GY	HI	GGR14	GGR21	GGR28
DH																					
DA	0.937*																				
PH	0.146	0.115																			
FL	0.012	0.043	-0.115																		
FB	0.144	0.058	0.034	0.133																	
FLA	0.058	0.037	-0.074	0.866**	0.600*																
T	0.057	0.084	0.025	0.867**	0.047	0.719**															
SL	0.201*	0.195*	0.202*	0.035	0.277*	0.176	-0.023														
SW	-0.113	-0.117	0.267**	0.145	0.082	0.170	0.065	-0.203*													
SPS	0.222*	0.204*	0.317**	0.137	0.148	0.196*	0.142	0.490**	0.105												
GPS	0.171	0.114	0.120	0.113	0.126	0.149	0.068	0.111	0.210*	0.631**											
GW	0.173	-0.166	-0.063	0.198*	-0.063	0.144	0.167	-0.246**	0.584*	-0.214*	-0.162										
GL	-0.136	-0.146	0.163	-0.053	-0.230*	-0.157	-0.026	0.045	0.039	-0.062	-0.057	0.331**									
GB	-0.199*	-0.187*	0.020	0.094	0.113	0.139	0.081	-0.073	0.090	-0.197*	-0.240*	0.369**	0.120								
TGW	-0.126	-0.105	-0.026	0.131	-0.064	0.088	0.114	-0.199*	0.577*	-0.194*	-0.164	0.931**	0.359*	0.344*							
BY	0.020	0.043	0.379**	0.016	-0.113	-0.056	0.035	0.188*	0.156	0.204*	0.006	0.051	-0.013	0.029	0.106						
GY	0.065	0.085	-0.014	0.815**	0.090	0.689**	0.866**	-0.064	0.166	0.046	0.037	0.224*	0.017	0.082	0.198*	0.120					
HI	0.018	0.014	-0.333**	0.523**	0.136	0.491**	0.544**	-0.218*	-0.009	-0.159	0.005	0.138	0.047	0.048	0.070	-0.740**	0.568**				
GGR14	-0.104	-0.032	-0.159	0.023	-0.162	-0.048	0.027	-0.179	0.130	-0.239**	-0.315*	0.338**	0.172	0.043	0.424*	-0.083	0.034	0.086			
GGR21	-0.113	-0.043	-0.065	0.256**	-0.169	0.120	0.222*	-0.148	0.130	-0.177	-0.024	0.260**	-0.052	0.071	0.152	-0.156	0.112	0.186*	0.132		
GGR28	-0.138	-0.104	0.010	0.333**	0.142	0.333**	0.323**	-0.258**	0.236*	-0.100	-0.053	0.376**	-0.139	0.316*	0.311*	-0.095	0.227*	0.224*	-0.010	0.363**	

Table.4 Phenotypic correlation coefficients among yield and seed quality parameters

	BY	GY	GM	SLg	SD	V-I	V-II	Sd	SH	Dr. H	FE	FS
BY												
GY	0.120											
GM	0.171	-0.062										
SLg	-0.098	-0.200*	0.285**									
SD	0.123	0.097	0.214*	-0.007								
V-I	-0.005	-0.181*	0.658**	0.909**	0.087							
V-II	0.156	0.072	0.457**	0.071	0.966**	0.254**						
Sd	0.079	-0.143	0.207*	0.119	-0.068	0.186*	-0.007					
SH	0.036	-0.168	0.033	-0.388**	0.014	-0.292**	0.022	0.018				
Dr. H	0.052	-0.036	-0.089	-0.261**	-0.057	-0.245**	-0.076	0.047	0.639**			
FE	-0.016	-0.167	0.675**	0.203*	0.329**	0.453**	0.480**	0.203*	0.122	-0.130		
FS	0.071	-0.080	0.027	0.265**	0.369**	0.219*	0.345**	-0.024	0.075	0.122	0.180*	

*significant at 5 per cent; **Significant at 1 per cent

BY: Biological yield (g); GY: Grain yield (g); GM: Germination%; SLg: Seedling length (cm); SD: Seed dry weight (g x 10⁻³); V-I: Vigour index –I; V-II: Vigour index-II; Sd: Seed density(g/cc); SH: Straight plant height(cm); Dr. H: Plant drooping height (cm); FE: Field emergence index; FS: Seedling establishment(%).

The negative association of plant height with harvest index (-0.333**) is due to the fact that an increase in plant height leads lodging, thereby decreasing the grain yield.

Flag leaf length was positively associated with flag leaf area (0.866**), number of tillers per meter (0.867**), grain weight per spike (0.198*), harvest index (0.523**), grain growth rate at 21 days (0.256**) and 28 days (0.333).

Grain weight per spike was positively correlated with grain length (0.331**), grain breadth (0.369**), 1000 grain weight (0.931**), grain growth rate at 14, 21 and 28 days (0.338**, 0.260**, 0.376**, respectively). Selection of these characters will increased the grain yield. Germination percentage (Table 5) showed positive correlation with seedling length (0.285**), seedling dry weight (0.214*), vigour index-I (0.658**), vigour index-II (0.457**), seed density (0.207*) and field emergence index (0.675**), which indicated that by increasing these attributes, germination percentage will be increased.

The two stages viz. seedling emergence and grain growth rate influence the grain yield in NWPZ. Seedling emergence can be improved by increasing the germination percentage and vigour index-II.

Grain growth rate is affected by days to 50% heading and grain filling rate. Selection for medium days to 50% heading (93-98 days) and medium maturity (140days) is best for developing high yielding genotypes for normal sown condition of the NWPZ of India.

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