Relationships among duration of vegetative and grain filling periods, yield components and grain yield in durum wheat

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SUMMARY

The relationships between the duration of vegetative and grain filling periods, grain yield and yield components were investigated on 23 durum wheat cultivars and breeding lines grown under three seeding dates at the Agricultural Research Station, Setif (Algeria). The results indicated that duration of vegetative period (thereafter VEGP) was negatively correlated with grain yield, head/m^2, kernel weight and duration of grain filling period (GFP). Path coefficients analysis revealed that VEGP had a consistent and negative direct effect on the duration of GFP. The direct effects of GFP were positive on kernels per head and kernel weight but these effects were less strong as seeding date was delayed. Head/m^2 had negative direct effects on kernels per head and kernel weight. Kernel per head, head/m^2 and kernel weight had positive direct effects on grain yield. Based on these results, selection for an optimum vegetative duration to improve grain yield appears to be a worthwhile objective for the high plateaux region, provided that the resultant early heading does not result in an increased sensitivity to late spring frosts.

Keys words: *Triticum durum*, vegetative period, grain filling period, grain yield, correlation, high plateaux, Algéria

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RESUME

Titre: Relations entre la phase végétative, la phase de remplissage du grain, les composantes du rendement et le rendement du blé dur

Les relations entre la durée de la phase végétative et celle du remplissage du grain, le rendement et ses composantes ont été étudiées chez 23 génotypes de blé dur semés à trois dates au niveau de la Station Experimentale Agricole de Setif (Algérie). Les résultats indiquent que la durée de la phase végétative est négativement corrélée au rendement, au nombre d'épis/m^2, au poids du grain et à la durée de la phase de remplissage du grain. L'analyse des relations directes et indirectes (Path coefficient analysis) révéle que la durée de la phase végétative a un effet direct et négatif sur la durée de la phase de remplissage du grain. Les effets directs de la durée de la phase de remplissage du grain sont positifs sur le nombre de grains/épi et le poids du grain. Ces effets diminuent d'intensité à mesure que le semis est tardif. Le nombre d'épis a des effets directs et négatifs sur le nombre de grains/épi et sur le poids du grain. Le nombre d'épis, le nombre de grains/épi et le poids du grain ont des effets directs et positifs sur le rendement. Sur la base de ces résultats, la sélection pour une durée optimale de la phase végétative pour améliorer le rendement semble un objectif intéressant pour la région des hauts plateaux, pour peu que la précocité n'aboutit à un accroissement de la sensibilité vis à vis des gels tardifs du printemps.

Mots clés: *Triticum durum*, phase végétative, phase de remplissage du grain, corrélations, rendement, hauts plateaux, Algérie

ملخص

العنوان: العلاقة بين مرحلة النمو الخضري ومرحلة ملء الحبوب ومكونات المردودية ومردودية الحبوب عند القمح الصلب

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درست الروابط بين مدة النمو الخضري و ملء الحبوب لدى 23 مجموعة وراثية من القمح الصلب زرعت خلال ثلاث فترات بمحطة التجارب الزراعية بسطيف (الجزائر). توضح النتائج بأن مدة النمو الخضرى تنعكس سلبيا على المردودية، على عدد السنابل بالمتر المربع، على وزن الحبة و على مدة ملء الحبوب. وكشف تحليل العلاقات المباشرة والغير المباشرة بأن لمدة النمو الخضري تأثير مباشر وسلبي على مدة مرحلة ملء الحبوب، كما أن التأثير المباشر لمدة ملء الحبوب إيجابي على عدد الحبات بالسنبلة وعلى وزن الحبة. لكن هذه الآثار تقل حدتها كلما كان البدر متأخرا. كان لعدد السنابل تأثير مباشر وسلبيي على عدد الحبات بالسنبلة وعلى وزن الحبوب. كل من عدد السنابل، عدد الحبات بالسنبلة ووزن الحبوب كان لهم أثر مباشر وإيجابى على المردودية. وعلى ضوء هذه النتائج ، يتبين أن انتخاب الأصناف على أساس مدة أمثل لمرحلة النمو الخضري يظهر هدفا مهما من أجل تحسين المردودية بالنسبة لمنطقة الهضاب العليا، لكن لا يجب أن يؤدي الإبكار إلى الزيادة فى حساسية الأصناف اتجاه الصقيع المتأخر فى فصل الربيع.

الكلمات المفتاحية : القمح الصلب، مرحلة النمو الخضرى، مرحلة ملء الحبوب، علاقة، مردودية، الهضاب العليا، الجزائر

INTRODUCTION

In the semi-arid areas durum wheat yield is limited by source and sink capacities both of which are under the control of temperature and water availability (Fisher and Kertesz 1967). In the high plateaux of Algeria almost all of the durum crop is rainfed and is grown in an environment with high temperature fluctuations characterized by late frost and high evapotranspiration (Hachemi 1979; Vagugheze and Srivastava 1979). Earliness is seen a mechanism to escape drought (Levitt 1972), however material that flowers too early may be damaged by late frost (Hosino and Tahir, 1987; Mouret *et al.* 1990). Genotype with a long vegetative period and a short reproductive phase, seem more appropriate (Varugherse and Srivastava 1979). Late heading allows cultivars to escape late frost whereas early maturity minimizes the effect of drought and heat stresses during grain filling period (Hoshino and Tahir 1987).

Identification of desirable agronomic traits which provide plasticity to allow plant to cope with highly variable and impredictable environment is needed. In this respect Coffman and Frey (1961) reported that late heading genotypes are more susceptible to yield reduction when water and high temperature stresses occur during grain filling. Tahir (1987) reported that locally adapted and successful varieties in high altitude semi-arid environments possess high level of cold tolance, high fertile tiller number size spikes and kernels. Bingham (1969) noted that grain yield is directly dependent in sink size which is largely determined during the vegetative period and on photosynthesis capacity of the crop during the grain filling phase. Nass and Reiser (1975) concluded that length of the grain filling period was not important in determining grain yield in durum wheat. Gebeyehou *et al.* (1982) found that grain yield was positively corrected with duration of the grain filling period but not with vegetative period. The experiment described here was carried out to investigate the relationship existing between grain yield component and duration of the vegetative and grain filling periods in durum wheat grown under semi-arid condition.

MATERIAL AND METHODS

A field experiment was carried out in 1991/92 at the Agricultural Experiment Station of Setif, Algeria. The experimental site is located 36°9 N lattitude and 5°21 E longitude at 1100 m altitude. The soil is a brown calcarous and the land has been fallowed the year before. 23 durum varieties and advanced lines (Table 1), were under rainfed conditions. Three seeding dates (October 27, December 7 and January 8) were used. The experiments, one per seeding date, were laid out in randomized complete block design with three replications. Seeding rate was 300 viable seeds per m^2. Each plot was 6 rows, 0.20 m apart and 10 m long. 46 kg of superphosphate per hectare were applied before seeding and 35 kg of N as ammonium nitrate at the tillering stage. Broad leaves were controlled with 3.5 l per ha of Illoxan B herbicide. Rainfall accumulate from october first to june 30th was 399 mm. Harvest was done on july 7th 1992.

Table 1. Durum wheat varieties studied

Number	Name	Number	Name
1	Mohamed Ben Bachir	2	Gloire de montgolfier
3	Guemgoum	4	Polonicum
5	Bidi 17	6	Oued Zenati
7	Montpellier	8	Capeiti
9	Hedba 3	10	Oued Safsaf
11	Hidhab	12	Sahel
13	Mexicali	14	Vitron
15	Waha	16	Boussalem 9
17	Boussalem 7	18	Haurani
19	Boussalem 1	20	Bazer
21	Bouamama	22	Laghmara
23	Karasu		

Days to heading (VEGP) were calculated as the number of days from January first to anthesis. Grain filling was calculated as the number of days from anthesis to physiological maturity (GFP), days to maturity as the sum of the days in VEGP and GFP. At maturity a 1.2 m^2 sample (3 times one segment of 1 m x 2 rows) was taken from each plot measurements of spikes/m^2 (SN), plant height (PHT), biological yield (BIO), harvest index (HI) and kernel weight (TKW). The rest of the plots were mechanically harvested for grain yield estimates (GY). Kernels per head (KH) were derived as: $[GY_{(g/m\_)} \times 1000]/SN_{(m\_)} \times TKW_{(g)}]$

Grain filling rate (GFR) was calculated as grain yield (g/m^2) over the number of days in the grain filling period. Analyses of variance were conducted for characters measured on 3 replicates per experiment. Correlation coefficients, based on individual plot data, were calculated between all pairs of characters within experiment and a path coefficient analysis was carried out according to the model shown in figure 1. In this model assumptions were made that grain yield is the product of spikes/m^2 x kernels per head x kernel weight. Kernels per head and kernel weight (TKW) are influenced by the GFP. Grain filling period is affected by the duration of the vegetative period and spikes/m^2.

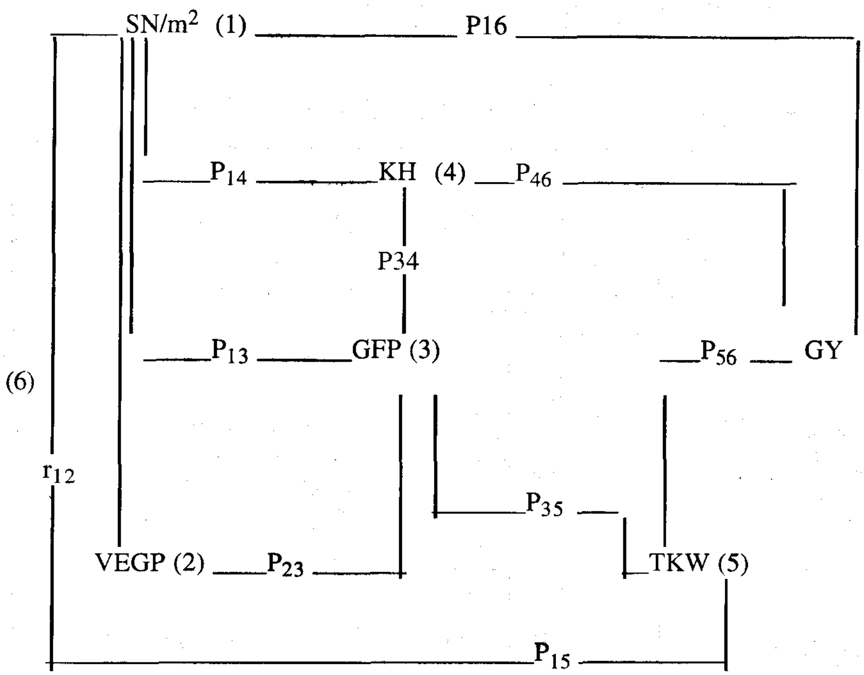

Figure 1. Path diagram model tested

RESULTS AND DISCUSSION

Significant differences existed among cultivars and lines tested for all characters measured per experiment. Delaying seeding date from October to January decreased grain yield by 17.4%, spikes/m^2 by 25.8%, plant height by 14.8% biomass by 37.8% and grain filling rate by 14.9% as averaged over the 23 Durum genotypes tested. Little variation was observed in kernel weight between environement index and kernels per head as seeding date was delayed (Table 2). This could be attributed to a better harmony between plant parts leading to an increase in the efficiency of ressources allocation (better HI). The increase in kernels per head could be due to the positive effect drought by the reduction in spikes/m^2 and probably to the negative effect of frost on early material. Mouret *et al.* (1990) reported such weather accident on early genotypes.

Means and ranks for the growth periods of the 23 genotypes are reported in Table 3. The ranking of the genotypes for the duration of vegetative and grain filling periodes was almost constant, except for the genotypes 17 and 23, whose ranking differed between environment for the vegetative period of growth. The ranges between genotypes, of the number of days in the vegetative period were 17, 12 and 15 days, while they were 11, 8 and 7 days for the grain filling period of the early, intermediate and late seeded experiments (thereafter E1, E2 and E3 respectively), indicating more variation in vegetative than in grain filling period.

Table 2. Means and ranges of 8 characters measured on 23 durum wheat grown at Setif in 1992

Characters	Experiments					
	E1		E2		E3	
	mean	range	mean	range	mean	range
GY (g/m^2)	404	281-610	422.1	304-633	34.1	21.9-49.3
SN/m2	613	434-777	465	382-605	455	377-535
KH	14.7	8.2-22.2	20.7	13.4-30.7	17.4	10.5-25.7
TWK(g)	45.3	35.1-51.3	44.1	37.3-50.8	44.3	38.9-49.0
PHT(cm)	101.3	96-128**	90.5	67- 20**	86.3	64.116
BIO(g/m^2)	1961	1731-2240	1362	1092-1629	1218	923-1451
HI(%)	0.20	0.13-0.32	0.31	0.20-0.45	0.28	0.17-0.39
GFR	12.2	07.9-16.5	12.7	09.8-17.5	10.6	06.2-14.0

Based on sample standard error (SE), short duration lines (mean VEGP. Trial mean VEGP-SE) and long duration lines (mean VEGP. Trial mean VEGP+SE) were sorted out from the 23 genotypes (Table 4). Short duration lines spent almost 7 days more in the grain filling period as compared to long duration lines. Rasmusson et al. (1979) found that long duration lines spent an average of 7 days longer in grain filling period than short duration lines. Short duration genotypes were characterised by high grain yield, spikes/m^2, grain filling rate, kernel weight and a long grain filling period of growth. The differences in kernels per head, plant biomass and days to maturity were not enough important to discriminate between groups. However plant height was significantly shorter in short duration genotypes (Table 4). The ratio of the number of days spent in VEGP to the number of days spent in grain filling period was 3:1 and 4:1 respectively in short and long duration genotypes. Apparently variation in growing conditions (seeding dates) had an effect on the performance of the groups rather than on the differences between them for the differents characteristics.

Table 3. Means and (ranks) of the growth periods for 23 Durum genotypes grown under 3 different environments in a semi-arid region

Genotypes	Environments					
	E1		E2		E3	
	VEGP*	GFP	VEGP	GFP	VRGP	GFP
1	120 (9)	36 (18)	108 (9)	32 (13)	116 (7)	36 (12)
2	123 (15)	33 (10)	108 (9)	31 (10)	118 (13)	34 (18)
3	123 (15)	32 (6)	108 (9)	31 (10)	118 (13)	32 (7)
4	122 (13)	32 (6)	108 (9)	29 (2)	117 (9)	33 (12)
5	120 (9)	34 (12)	105 (5)	36 (21)	114 (5)	37 (23)
6	122 (13)	33 (10)	109 (14)	32 (13)	118 (13)	32 (7)
7	123 (15)	32 (6)	108 (9)	33 (17)	118 (13)	32 (7)
8	114 (4)	37 (20)	104 (4)	35 (19)	115 (6)	31 (3)
9	120 (9)	36 (18)	109 (14)	31 (10)	117 (9)	35 (19)
10	127 (23)	34 (12)	113 (22)	28 (1)	121 (23)	31 (3)
11	118 (5)	35 (16)	105 (5)	34 (18)	106 (1)	31 (3)
12	119 (7)	34 (12)	107 (7)	32 (13)	117 (9)	30 (1)
13	111 (2)	38 (22)	102 (2)	36 (21)	112 (3)	35 (19)
14	112 (3)	38 (22)	103 (3)	35 (19)	113 (4)	33 (12)
15	110 (1)	37 (20)	101 (1)	36 (21)	109 (12)	35 (19)
16	121 (12)	32 (6)	107 (7)	32 (13)	116 (7)	32 (7)
17	119 (7)	35 (16)	109 (14)	30 (8)	118 (13)	30 (1)
18	125 (19)	27 (1)	110 (18)	29 (2)	118 (13)	33 (12)
19	124 (18)	30 (4)	110 (18)	29 (2)	118 (13)	33 (12)
20	125 (19)	29 (2)	109 (14)	29 (2)	118 (13)	33 (12)
21	126 (21	29 (2)	111 (21)	29 (2)	119 (21)	32 (7)
22	126 (21)	30 (4)	113 (22)	29 (2)	120 (22)	31 (3)
23	118 (5)	34 (12)	110 (18)	30 (8)	117 9)	33 (12)
G. Mean	120.3	33.3	107.3	31.6	116.2	32.7
SE	4.8	3.0	3.2	2.6	3.4	1.8
Range	17	11	12	8)	15	7

* = days from January 1st

Table 4. Characteristics of 2 groups of durum genotypes with short and long vegetative periods of growth

Characters	Environments					
	E1		E2		E3	
	Short	Long	Short	Long	Short	Long
GY (g/m^2)	478	373**	563	353**	430	317**
SN/m^2	652	589**	504	408**	495	418**
KH	28.2	32.1*	33.2	33.9 ns	30.8	29.2 ns
TWK(g)	48.8	41.8	43.0	40.6**	46.4	41.4**
BIO (g/m^2)	1897	2000 ns	1279	1243 ns	1181	1213 ns
PHT(cm)	90	99**	72	94**	68	87**
VEGP (days)	102	112	109	120	111	126
GFP (days)	35.7	28.7	35.3	28.7	37.7	31.0
GFR ($g/m^2/day$)	13.4	12.9	15.9	12.3**	11.4	10.2**
DMAT (days)	137.7	140.7	144.3	148.7	148.7	157.0

SE: SN=40.2; GFR=0.6; KH=2.6; TKW=1.4; PHT=3.5; BIO=369 and GY=3.2

The study of the relationships between traits indicated that vegetative period was negatively corrected with grain yield, spikes/m^2, harvest index and grain filling period. Rasmusson et al. (1979) reported a negative correlation between vegetative and grain filling periods in barely. Duration of the vegetaitve period showed no relationships with kernels per head, grain filling rate and kernel weight (Table 5). Grain filling period had positive effects on spikes/m^2 and kernel weight of E3 and on kernel weight of E1 only. This indicated that cultivars characterized by a high production of spikes/m^2 tended to have a short vegetative period. Modern varieties in the semi-arid region are characterized by relatively high spikes production and earliness (Siddique, 1989). Kernels per head was positively corrected with HI and GFR. The relationship between GFR and kernels per head indicated that the more kernels per head, the higher will be the GFR to fill adequatly those kernels, since there was little variation in the GFR to fill height was negatively corrected with HI and GFR in the normal and late seeded experiments indicating that taller lines tended to have low HI and GFR, resulting in lower GY. For the same experiments the correlation coefficients between plant height and GY were negative (Table 6). HI was negatively correlated with VEGP and positively correlated with GFR.

No relationships existed between grain filling period and grain yield. These results supported partially the findings of Nass and Reiser (1975) who reported no relationships between grain yield and days to anthesis and between grain yield and days in grain filling period. Yasuda (1978) found that late heading was positively correlated with grain yield, kernels per head and spikes/m^2.

Gebeyou *et al.* (1982) reported also positive correlations of grain filling with kernels/head, kernel weight and grain yield.

Path coefficients analysis showed that vegetative period had a negative and strong direct effect on GFP (Table 6). This supported the fact that variation in GFP was dependent on the duration of the vegetative period at least under the vegetative period at least under the growing conditions of the high plateaux. the direct effect of spikes/m^2 was negligible to moderate on GFP, high on GY and negative on kernels per head and kernel weight. The direct effects of GFP on kernels and kernel weight were positive and variable in magnitude depending on each experiment. Kernel weight and kernels per head had moderate to high direct effects on grain yield. Under the growing conditions of the high plateaux, days to maturity tends to assume a relatively fixed value. This is probably due to the effects of late season drought and high temperatures which haten the termination of crop growing cycle, leaving more variation in the duration of vegetative period. Thus a line with a short vegetative period has a relatively long period, while a long vegetative period is made possible through reduction in the GFP, which forces the crop to fill its kernels in fewer days increasing the GFR. However the increase in GFR compensates for a reduced GFR up to a certain level after which a decrease in crop grain yield is observed. These findings are in agreement with those reported by Matzger et al. (19984) and Samarrai et al. (1987) who found no relationship between GY and GFP. The low variation in GFP is componsated by more variation in GFR which is highly correlated with GY (Table 5) Whych *et al.* (1982) reported that GFR was positively correlated with GY and days to heading, however in the present study the relationship between GFR and VEGP is non significant.

CONCLUSION

Several investigators have suggested that it should be possible to increase grain yield by achieving an optimum duration for the vegatative and grain filling periods of growth. The present results indicate that, in general. grain filling period was not important by itself in determining yield in the 23 genotypes studied, but it had positive direct effects on kernels per head and on kernel weight, which had strong positive directs effects on grain yield.

Vegetative period had a negative effect on grain yield through reduction of spikes/m^2, harvest index and grain filling rate. The effort to develop durum lines with long grain filling period could be successful because any increase in this growth period is mainly through reduction of the vegetative period. Days to heading is reported to be more heritable than days to maturity. Then reduction in the vegetative period should increase grain yield provided that the resultant early heading does not result in increased sensitivity to late spring frosts.

Table 5. Phenotypic correlations between pairs of characters measured on 23 durum cultivars

Traits	2	3	4	5	6	7	8	9	GFR 10
GY	.142	.115	**.803**	.273	-.327	**.964**	**-.425**	.279	**.889**
1	**.415**	.116	**.727**	**-.677**	-.030	**.824**	**-.693**	.305	**.829**
	.523	.359	**.523**	**-.633**	-.115	**.758**	**-.479**	.039	**.653**
SN		-.313	-.349	-.235	.070	.079	-.457	.243	.055
2		-.252	-.208	-.269	.200	.235	-.473	.410	.291
		-.068	-.117	-.047	.411	.055	-.656	.544	.162
TKW			-.071	.118	-.148	.156	-.339	**.446**	-.083
3			-.065	.017	.327	.118	-.124	.198	.088
			.116	-.290	.066	**.437**	-.294	-.091	.309
KH				-.143	-.304	**.796**	.013	-.016	**.815**
4				-.336	-.244	**.690**	-.389	.205	**.667**
				-.365	-.022	**.438**	-.075	.062	**.445**
PHT					.220	-.282	.111	.036	-.295
5					.350	**-.869**	.331	-.314	**-.840**
					.304	**-.893**	.330	.324	**-.758**
BIO						**-.556**	.286	-.115	-.300
6						-.308	-.268	-.114	.405
						-.277	-.236	.390	-.090
HI							-.445	.274	**.861**
7							-.433	.412	**.945**
							-.419	-.252	**.822**
VEGP								**-.842**	-.046
8								**-.711**	-.023
								-.523	-.191
GFP									-.184
9									-.300
									-.343

r (in bold) must exceed 0.414 and 0.526 to be significant at the 0.05 and 0.01 levels respectively

Table 6. Direct path coefficients for 5 traits measured on 23 durum genotypes

Traits	Trial	Direct effects of: SN	KH	KW	GFP	VEGP
GY	E1	0.6294	1.0507	0.3875		
	E2	0.6685	0.8932	0.3473		
	E3	0.41995	0.6497	0.3126		
KH	E1	-0.3675			0.3736	
	E2	-0.3508			0.3489	
	E3	-0.2145			0.1786	
KW	E1	-0.4486			0.5553	
	E2	-0.3991			0.3617	
	E3	-0.0270			-0.0759	
GFP	E1	-0.0656				-0.8659
	E2	0.0958				-0.6659
	E3	0.3528				-0.2911

E1= early; E2=normal and E3=late seeded experiments

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