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Relationship between Ear Primordia Development and Growth Attributes of Wheat Cultivars in Dry Areas of North Africa and West Asia

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Introduction

The growth cycle of wheat in winter-rainfall areas with annual precipitation of 200 to 600 mm in North Africa and West Asia*** is generally as follows: planting at the beginning of November, heading at the 3rd week of April, and harvest at the last week of May. Wheat encounters frost damage from January through March and then is exposed to drought stress from the middle of April and heat damage from the middle of May. As a strategy for obtaining high yield in these areas, there can be two ways to minimize the effect of stress occurring at different plant development stages. The one way is to get a long ripening period brought about by early heading for effective utilization of the limited soil moisture. The other way is to get rapid ripening within a short grain filling period after heading, after the plant has reached sufficient vegetative growth. The selection of breeding materials at ICARDA has been done by following the latter strategy, since wheat suffers seriously from early and late frost damage in ICARDA region.

To escape frost damage of wheat, the breeding program to develop early-maturing cultivars, characterized by late emergence of ear primordia onto the ground surface, followed by speedy development of the primordia, in other words late initiation of primordia and speedy growth of the primordia, was adopted in Japan with success. The ear primordia growing underground are protected from cold damage by soil layer. The primordia emerge onto the ground surface due to elongation of lower internodes at the VII stage of the primordia development (Table 2). Although they are enclosed within a group of leafsheath tissues, they become liable to suffer frost damage.

Since we do not have enough information about the relationship between frost damage, earliness, and ear primordia initiation of major wheat cultivars grown in dry areas of North Africa and West Asia, the growth performance of wheat cultivars in these areas was analyzed from a viewpoint of ear primordia initiation.

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Table 1. Characteristics of wheat cultivars and lines used in this study

Cultivar	Origin	Growth habit	Species	Comments
Sham 1	Syria	Spring	Durum	Developed by ICARDA/CIMMYT released in Syria in 1984
Sham 2	Syria	Spring	Aestivum	Developed by ICARDA/CIMMYT released in 1984
Haurani	Syria	Spring	Durum	Landrace cultivar commercially grown in Syria, Jordan and Lebanon
Gezira 17	Syria	Spring	Aestivum	Local old commercial cultivar in Syria
Kataya A-1	Bulgaria	Winter	Aestivum	See note 1)
Ogosta	Bulgaria	Winter	Aestivum	See note 1)
Trakia	Bulgaria	Winter	Aestivum	See note 1)
Vratza	Bulgaria	Winter	Aestivum	See note 1)
Pai yu Pao	China	Winter	Aestivum	See note 1)
CA-8055	China	Winter	Aestivum	See note 1)
NS-2699	Yugoslavia	Winter	Aestivum	See note 1)
Mexipak 65	Pakistan	Spring	Aestivum	Improved and suitable cultivar for irrigated areas
Zarghoon	Pakistan	Spring	Aestivum	Cold tolerant cultivar released in cooler areas in Pakistan
Bolal	Turkey	Winter	Aestivum	See note 2)
Bezostaja	USSR	Winter	Aestivum	Widely adapted cultivar grown in many countries
19 WOH 86*	Syria	Spring	Aestivum	See note 3), 4)
32 WOH 86*	Syria	Spring	Aestivum	See note 3), 5)
18 DOH 86*	Syria	Spring	Durum	See note 3), 6)
22 DOH 86*	Syria	Winter	Durum	See note 3), 7)
27 DOH 86*	Syria	Spring	Durum	See note 3), 8)
Fujimikomugi	Japan	Spring	Aestivum	High yielding cultivar in Japan
Avalon	England	Winter	Aestivum	Commercially cultivated in England

Note 1) Cultivars selected from international nursery. They are found suitable to cold area of West Asia and North Africa.
2) Drought and cold torelant cultivar, commercially cultivated in Central Anatolian Plateau in Turkey.
3) Nearly developed lines at ICARDA, performing well in cold areas of West Asia and North Africa.
4) *T. aest.* (Rom)//Tob 'S'/8156/3/Tx69A460-1/4/Emu 'S'=ICW 81-134-2AP-OAP.
5) Chambord/5133//Mt/3/KKC/4/Lfn//ND/2 *P101/5/Rom//CC/Inia=ICW 81-1610-1AP-2AP-OAP.
6) 18 DOH=Castel Porjiano/Boy 'S'.
7) Bit 'S'/Gdovz 394.
8) AA 'S'//3 *CPE/Gz//3 *TC/3/2 *Bye/TC/4/Fg 'S'/Gdovz 466.
* Breeding lines.

given an opportunity to stay in ICARDA to carry out a part of the cooperative research between ICARDA and the Tropical Agriculture Research Center, Japan.

Materials and methods

The materials used in this experiment were 17 cultivars and five breeding lines with different origin and growth performance (Table 1). They were planted at Tel Hadya Station of ICARDA in Syria on November 5, 1985. Eight days after planting, the experimental field was irrigated to promote the germination. Approximately five plants were randomly taken from drill strips and three moderate plants out of five per cultivar were used for the examination to record data on plant length (cm), tiller number (no./plant), stage of primordia development (Table 2),

Table 2. Definition of ear primordium developmental stages in wheat

Primordia stage		Magnification of microscope	Comments
I	Leaf primordium differentiation	×50	Impossible to classify these stages by microscope.
II	Ear primordium differentiation	×50	
III			
IV			
V (5)			
VI (6)	Early stage of spikelet primordium differentiation	×50	The vegetative stage is converting into reproductive stage.
VII	Middle stage of spikelet primordium differentiation	×20	
e (7.2)	Double protrusion at base		Clear double protrusion
l (7.7)	Roundish protrusion		Obscure double protrusion
VIII (8)	Late stage of spikelet primordium differentiation	×20	Culm elongation occurs and suceptible to frost damage
IX	Early stage of floret primordium differentiation	×20	Suceptible to frost damage in early spring
e (9.1)	Glume and first floret differentiation begins in spikelet		
m (9.4)	Lemma, stigma and anther differentiation in the middle part of ears		
l (9.7)	Lemma, stigma and anther differentiation from the top to base of ears		
X (10)	Late stage of floret primordium differentiation	×20	Awn development of the first floret
XI (11)			

This definition is cited from Inamura et al.[2]. Primordia at the stage of I to VI do not suffer from cold damage because primordia of leaf and ear are still under the ground. The stages are expressed by numerical score shown in parenthesis for the purpose of statistical treatment by the present authors.

primordia length (mm) and culm length (mm) at 93 days after planting (February 6, 1986), partially 97 days after planting (February 10, 1986) and at 117 days after planting (March 2, 1986).

The wheat did not encounter the severe frost damage during relatively mild winter of 1985/86, while the cold damage was apparent during harsh winter of 1984/85. Therefore, the frost damage score obtained in 1984/85 winter for each cultivar was employed in the present study.

Results

Great differences among wheat cultivars were observed in plant growth for various traits at 93 days and 117 days after planting, as shown in Table 3. The primordia initiation at 93 days after planting was at the stage V in Haurani and other 10 cultivars which were free from frost damage (Table 2) while it was at the IX_e stage in Sham 1 and other three cultivars which suffered frost damage. All characters except tiller number at 117 days after planting were bigger than those at 93 days after planting. Especially the culm elongated rapidly in all cultivars except Ogosta, Vratza, Pai yu Pao and Bezostaja. Cultivars at the stage V at 93 days after planting proceeded to the stage VII_e (Pai yu Pao, Gezira 17) to IX_m (Bolal). The primordia of Ogosta remained at the same stage, V, at 117 days as it was at 93 days after planting.

Great differences among wheat cultivars were observed in growth and yield performance as shown in Table 4. Cultivars CA 8055, Bolal and Bezostaja hardly suffered frost damage, while Sham 1, Mexipak 65, Zarghoon, Fujimikomugi and 3 breeding lines suffered frost damage. Fujimikomugi was the earliest and Avalon was the latest cultivar. Ogosta and Sham 1 showed higher yielding

Table 3. Differences in the length of primordia and culms among cultivars at 93 days and 117 days after planting

Cultivar	93 days after planting			117 days after planting		
	Primordia develop. stage	Primordia length (cm)	Culms length (mm)	Primordia develop. stage	Primordia length (cm)	Culms length (mm)
Sham 1	IX_e	2.1	15	X	12.0	180
Sham 2	IX_e	1.7	17	IX_l	5.0	119
Haurani	V	0.3	4	IX_e	2.7	96
Gezira 17	V	0.8	5	VII_e	2.8	18
Kataya A-1	VI	0.8	5	IX_m	4.2	48
Ogosta	V	0.4	4	V	0.8	5
Trakia	V	0.6	2	IX_e	2.6	14
Vratza	V	0.6	4	VIII	1.5	8
Pai yu Pao	V	0.4	4	VII_e	1.2	12
CA-8055	V	0.4	3	IX_e	2.8	45
NS-2699	V	0.4	3	VIII	2.0	17
Mexipak 65	VIII	1.4	10	IX_l	5.9	170
Zarghoon	VIII	2.4	12	X	5.7	131
Bolal	V	0.5	5	IX_m	2.3	44
Bezostaja	V	0.2	3	VIII	1.8	10
19 WOH 86	IX_e	1.8	18	IX_l	4.6	129
32 WOH 86	VIII	1.3	7	IX_l	4.1	63
18 DOH 86	IX_e	2.1	22	X	6.9	127
22 DOH 86	VI	1.3	8	IX_l	3.2	46
27 DOH 86	VII_e	1.3	10	IX_m	3.3	80
Fujimikomugi	IX_m	3.0	20	X	15.0	190
Avalon	V	0.4	3	VIII	1.9	21

ability with higher yield increase rate, and Sham 1 and 1 breeding line showed larger 1,000 kernel weight than others. Yield increase rate ranged from the maximum value of 191 g/day of Ogosta to a minimum value of 43 g/day in Fujimikomugi. The 1,000 kernel weight of Fujimikomugi was less than half that of cultivars released in dry areas.

Relationship between the primordia developmental stage of all cultivars and lines, examined 97 and 117 days after planting, and their growth performance (Table 4) was analyzed (Table 5). Frost damage was highly correlated with the primordia developmental stage examined on both dates, showing $r=0.866^{***}$ and $r=0.649^{**}$, respectively. The correlation between the number of days to heading and the primordia developmental stage at 93 days and 117 days after planting was also significant: $r=-0.721^{***}$ (Fig. 1) and $r=-0.607^{**}$, respectively. Growth habits (erect vs prostrate and winter vs spring type) were correlated significantly with the primordia developmental stage at 93 days after planting ($r=0.511^{*}$) but not at 117 days after planting ($r=0.292$). No significant correlation between growth habits and frost damage was observed ($r=0.383$). The grain yield obtained without sever frost damage in 1986 was not correlated significantly with the frost damage in harsh winter of 1984/85 ($r=0.029$).

Highly significant correlations were observed between the primordia developmental stage and primordia length or culm length measured on the same dates assessing the primordia stage.

Discussion

The growth habits have been used as a convenient and simple index of wheat growth performance. However, they are not always correlated with the primordia developmental

Table 4. Growth and yield performance of cultivars tested

Cultivar	Growth habit	Frost damage	Days to heading	Days to maturity	Ripening duration	Yield (t/ha)	Yield increase rate (g/day)	1,000 kernel weight (g)
Sham 1	3	5	171	211	40	6.44	162	45.7
Sham 2	3		172	213	41	5.46	133	29.8
Haurani	3	2	178	214	36	4.35	121	43.8
Gezira 17	3	2	185	227	42	4.93	117	43.9
Kataya A-1	2	2	175	216	41	4.80	117	40.3
Ogosta	2	2	182	218	36	6.88	191	43.4
Trakia	1	2	179	218	39	5.02	129	40.0
Vratza	2	2	174	211	37	5.51	149	46.6
Pai yu Pao	1	2	174	209	35	1.91	55	28.6
CA-8055	1	1	182	218	36	4.43	123	43.4
NS-2699	2	2	183	224	41	5.06	123	44.4
Mexipak 65	3	5	175	212	37	2.31	62	30.4
Zarghoon	2	5	172	213	41	6.35	155	37.3
Bolal	2	1	178	223	45	2.93	65	37.5
Bezostaja	1	1	185	222	37	4.17	113	43.0
19 WOH 86	2	4	171	211	40	3.42	86	44.2
32 WOH 86	2	4	175	212	37	5.86	158	40.3
18 DOH 86	2	5	171	213	42			
22 DOH 86	1	5	179	216	37	4.31	116	49.1
27 DOH 86	2	5	180	217	37	4.71	127	43.6
Fujimikomugi	3	5	163	206	43	1.87	43	21.5
Avalon	1	2	196	228	32	2.89	90	30.1

Note 1) Growth habit: 1=prostrate, 2=semi prostrate, 3=errect.
2) Frost damage: 1=small, 3=medium, 5=severe.

Table 5. Correlation coefficients between primordia developmental stage (P. D. S.) and growth attributes

Time P. D. S. assessed (days after planting)	Primordia length	Culm length	Growth habit	Frost damage	Days to heading
97	0.919***	0.936***	0.511*	0.866***	-0.721***
117	0.729**	0.778***	0.292	0.649**	-0.607**

*, **, *** Significant at 5, 1 and 0.1% level.

stage, and hence no significant relation was observed between growth habits and frost damage. Instead, highly significant relation was observed between the primordia developmental stage and frost damage. To breed new lines for cold tolerance at ICARDA, the frost damage must be taken into consideration for screening breeding materials. The more effective way to select the breeding lines which can escape the frost damage will be to study the time of primordia initiation[2] and the duration of low temperature required for inducing heading[1]. In this connection, it must be added that wheat cultivars of winter and spring types were classified into seven categories (I–VII) depending on the duration of low temperature required for heading.

As given in Table 4 and Fig. 1, significant correlation was found between primordia developmental stage and days to heading in this study. Cultivars characterized by late primordia initiation and early heading are the best while cultivars with early primordia initiation and late heading are the worst in growth performance from the viewpoint of escaping frost damage. Among the cultivars

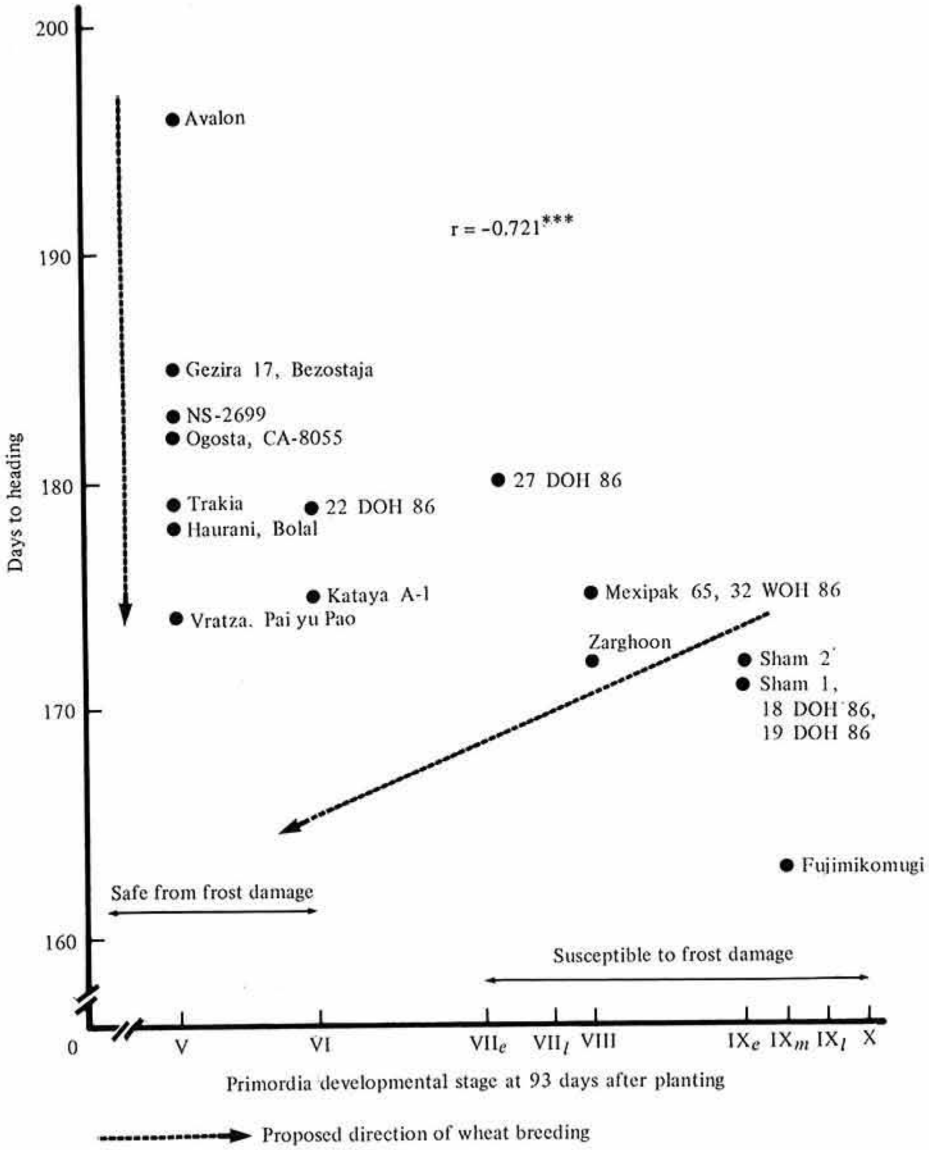

Fig. 1. A correlation between the ear primordia developmental stage and the number of days to heading, indicating our proposal of the direction of cultivar improvement toward late primordia initiation and early heading to avoid frost damage

used in this study, Pai yu Pao showed the ideal type of late primordia initiation and early heading though it has no high yielding ability as compared with others, while Sham 1 has high yielding ability with larger kernel weight, although its ripening duration was relatively short (Table 4). This suggests that it is possible to combine the early maturity with late primordia initiation and the high yielding ability with a short grain filling period by directed breeding efforts in dry areas.

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