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Predicting the effect of temperature on leaf appearance in seven spring bread wheat genotypes

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ABSTRACT: Field experiments were conducted at the Faculty of Agriculture, Cairo University, Agriculture Experiment and Research Station, during two successive seasons starting with 2010/2011 in Giza, Egypt. The study aimed to determine the effect of temperature (by sowing dates) on leaf appearance and growth of seven spring bread wheat genotypes. Linear response was found between rate of leaf appearance and thermal time. Phyllochron ranged between 108°C d and 122°C d. Mean final leaf number on the main stem ranged from 8.5 to 11.5 and it was highly correlated with thermal time (r=0.99**). Genetic constitution of genotypes had larger effect on number of leaves per main-stem than temperature. These results suggests that, to model leaf appearance and canopy development in wheat, genotypic coefficients of phyllochron need to be determined in relation to growing environment temperature.
Keywords: Phyllochron; Leaf number; Thermal time; Triticum aestivum L.

INTRODUCTION

Growth and development of leaves are important determinants of economic yield of crops because dry matter accumulation depends on the number and area of leaves that intercept light (Ishag et al., 1998). Generally, growth and development occur simultaneously inclusive nor exclusive. Under specific conditions, development may occur without the growth and vise versa. Sometime development may be advance, while growth stopped due to environmental stress frequencies (Wilhelm and McMaster, 1995). An example of simultaneous development and growth is Haun stage. Because most Haun development stages are defined by the ratio of leaf length, if leaves do not grow, there is no change in lengths, so there are no measurements of development. Several terms have been used to detect rate of leaf appearance: plastochron, auxochron, and phyllochron. The first plastochron was defined by Askenasy (1880), then cited by Erickson and Michelini (1957), as the interval between formation of two successive internode cells in Nitella flexilis. Later, the term was expanded in definition to: the time interval between the initiation of successive primordial on shoot apex (Esau, 1965; Milthorpe, 1956). However, some investigators (Erickson and Michelini, 1957) have attempted to further expanded the definition to include any other stage of development as a reference point. Hancock and Barlow (1960) suggested the term auxochron as the interval between comparable stages on successive leaves on a stem. This term has been little use. Bunting and Drennen (1966) proposed the term phyllochron as the interval between appearance of successive leaves on a clum or stem. The phyllochron interval (°C d leaf^{-1}) is a more accurate measure of stem and tiller development (Klepper et al., 1982) than earlier systems of accessing development (e.g., Zadoks et al., 1974).

The phyllochron can be determined in many ways, such as documenting the time of appearance of successive leaves on a Culm or measuring the time it takes for an individual leaf to grow (Wilhelm and McMaster, 1995). The latter method assumes that the leaf grows within the time of one phyllochron, which may be the case in some species, but not in others. That is, in some species leaf n+1 may appear before leaf n has completed growth. In practice, the Haun scale (Haun, 1973) is often used to determine the phyllochron during vegetative development of grasses. However, the interval between the events may be measured either in time, thermal time or other meaningful measurements of time. Development and growth of grasses are characterized by the repeated formation of a basic unit, the phytomer. There is an intrinsic relationship between the concepts of phytomer unit and the phyllochron. So, development can be conceptualized by the addition of successive phyllochron units (Wilhelm and McMaster, 1995).

A number of environmental factors have been reported to affect the pyllochron. Most of effects environmental factors are complex. Masle et al., 1989; Cao and Moss, 1989; Boone et al., 1990 a found that increasing temperature lead to increase phyllochron. On the contrary, Longnecker et al., 1993 found increasing nutrient availability cause decrease phyllochron. However, Bauer et al., 1984; Frank and Bauer, 1982 found no change in phyllochron with increasing nutrient availability. Baker et al., 1986 found that increasing water lead to increase phyllochron. For the influence of salt Maas and Grieve, 1990 found increasing salt lead to increase phyllochron. Also there was no change in phyllochron by increasing CO_2 (Boone and Wall, 1990 b).

The purpose of this paper is to present the role temperature (by sowing dates) and plant genetic in determining the phyllochron of seven spring bread wheat genotypes and to predict the impact of temperature on leaf appearance.

MATERIALS AND METHODS

Experimental practices

Experiments were conducted at the Faculty of Agriculture, Cairo University, Agriculture Experiment and Research Station, during two successive seasons starting with 2010/2011 in Giza Governorate (30.029°N 31.207°E)., Egypt. The soil texture was silt-loam (21% clay, 54% silt and 25% sand) with 3.2% organic matter and a pH of 7.84. Absorbable N, P and K were 1.12%, 0.08% and 0.20%, respectively.

Weather

Daily temperature (maximum and minimum) during the 2010/2011 and 2011/2012 growing seasons were obtained from the Central Laboratory for Agriculture Climate (CLAC), A.R.C. Egypt, and are shown in Fig. 1. Daily maximum temperature fluctuated more than minimum temperature. Maximum and minimum temperatures were usually high, but were cooler from mid-December till the end of January. Warm air temperatures persisted longer in 2011/2012 compared to season 2010/2011.

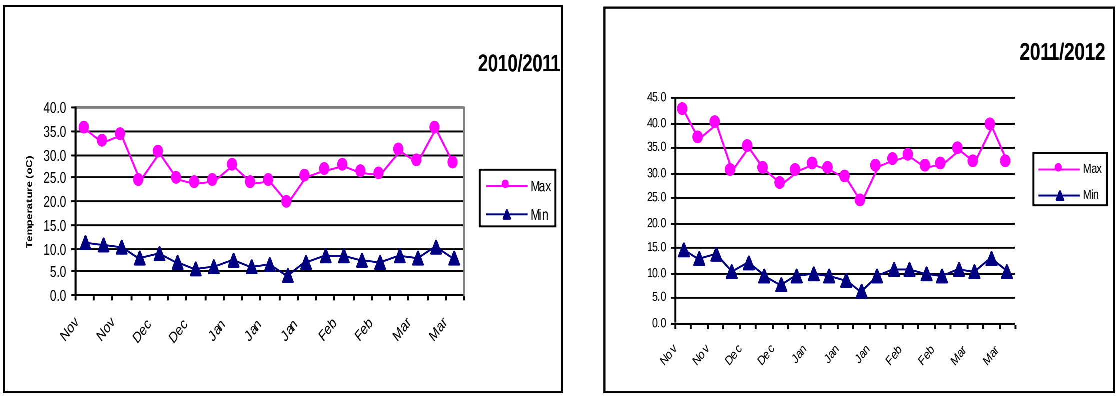


Figure 1. Daily temperature (maximum and minimum) during the 2010/2011 and 2011/2012 growing seasons.

Seven bread wheat genotypes were chosen for study based on their reputed differences in yield performance and maturity. The pedigree and origin of the studied genotypes are listed in Table 1 Two sowing dates for the two growing seasons were as follows: 2010/2011: 21 November; and 20 December 2011/2012: 20 November; and 20 December. Each plot consisted of four rows, 3 m long and spaced 20 cm apart. The two central rows were used for yield measurements and observations. All genotypes were sown by a seed drill at a seed rate of 150 kg ha^{-1}. The experiment was managed in randomized complete block design with four replications.

Table1. Names, pedigrees and origins of the studied genotypes.

No.	Genotypes	Pedigree	Origin*
1	Sakha 69	Inia/RI 4220//7C/3/Yr	Egypt
2	Gemmeiza 1	Maya74/on//1600 147/3/BB/GALL	Egypt
3	Sids 1	HD2172/2/Pavon//1158.57/Maya	Egypt
4	Nesser	W3918A/JUP	Jordan
5	HD 2380	Not available	India
6	Yocoro Rojo	CNO//SON64/RLRE/3/8156	USA
7	Kavko	KVZ/3/ CNO/CHR// ON SE375	Turkey/Kenya

*Source: CIMMYT Semi-dwarf Bread Wheat's Names, Pedigrees and Origins.

Sampling procedures and measurements

Stages on Haun (1973) growth scale were established on five tagged plants in each replicate every 4 or 5 days; the number of emerged leaves on the main stems were recorded at the same time. Leaf appearance was calculated by plotting the number of emerged leaves against accumulated thermal time. Thermal time or growing degree days (GDD) was computed from the following equations:

$$T_t = \frac{T_{max} + T_{min}}{2} - T_{base}.$$

Where T_{max} is the daily maximum air temperature, T_{min} is the daily minimum air temperature, and T_{base} is the temperature below which the process of interest does not progress.
Phyllochron interval (PI) was calculated as the reciprocal of the slope of the linear regression of Haun-scale growth units against accumulated thermal time (GDD) (Baker et al., 1986).

In order to phyllochron measurement during growth season each 3 days one time existing leaves numbers in three plants from main lines each plot was calculated when every leaf minimum 1 centimeter of length had. Meanwhile three selective plants were marked by color string and every leaf was marked by color pen after counting. Leaf appearance rate was calculated by the following equation:

$$\text{Leaf appearance rate} = \frac{1}{phyllochron}$$

Finally, the data were statistically analyzed by MSTAT-C V.2.1 (Russel, 1994). The mean differences among the treatments were compared by least significant difference test at 5% level of significance (Steel et al., 1997).

RESULTS AND DISCUSSIONS

Phyllochron

Data in Table 2 show mean phyllochron (^{o}C d) from sowing to appearance of flag leaf during studied growing seasons as affected by sowing dates and genotypes. Results revealed that phyllochron values were highly significant different between sowing dates and genotypes in both growing seasons.

Phyllochron values for the first date (121 ^{o}C d) was higher than the second date (110 ^{o}C d) in both seasons. This response agrees with the finding of Cao and Moss, 1989. However, the values of Phyllochron interval (PI) during the two growing seasons for genotypes ranged from 108 to 121 with an average of 166. HD 2380 was the lowest value for PI in both seasons, while Kavko has the same value of PI in both seasons (121). Generally, Gemmeiza 1, Sids 1, HD 2380 and Kavko were lower in PI for first seasons comparing to second seasons. On the contrary, Sakha 69 and Nesser were higher in PI for first seasons comparing to second seasons. Previously reported phyllochron of wheat was 77^{o}C d (Frank and Bauer, 1995), 80^{o}C d (Bauer et al., 1984), 101^{o}C d (Kirby, 1988), 105^{o}C d (Biscoe and Willington, 1985) and 124^{o}C d (Baker et al., 1986). In this study, PI of the studied genotypes was 114 for first season and 117 for the second season with an average 116^{o}C d. All previous results were higher than reported may be due to high temperature that occurred during the growing seasons. However, these results were in harmony with those obtained by Ishag et al., 1998 (122^{o}C) and Cao and Moss 1994 were they indicated that plants of winter wheat grown at high temperature had larger PI than those grown in low temperature. The significant differences of genotypes for PI and the average air temperature during the period fluctuated considerably, from 6^{o}C to 35^{o}C indicated that genetic constitution of the genotypes had an effect may larger on PI than temperature.

Table 2. Mean phyllochron (^{o}C d) from sowing to flag leaf for seven spring bread wheat genotypes during 2010/2011 and 2011/2012 seasons as affected by sowing dates and genotypes.

	Season 2010-2011	2011-2012	Mean
Sowing dates			
Novmber	120	123	121
Decmber	108	112	110
LSD at 5%	6.18	4.87	3.13
Genotypes			
Sakha 69	120	114	117
Gemmeiza 1	113	121	117
Sids 1	119	124	122
Nesser	115	113	114
HD 2380	104	112	108
Yocoro Rojo	121	121	121
Kavko	108	117	112
LSD at 5%	11.57	9.11	5.86

Regression of number of leaves in the main culm vs. thermal time and the intercept, slope and correlation coefficient are given in Table 3. The correlation between appearance of leaves and thermal time was highly significant (r =0.99, $p<0.01$) and appearance rate of leaves was almost constant at 0.008-0.009 leaves (^{o}C d).

Table 3. Intercept (a), slope (b), and correlation coefficient (r) of regression lines for number of leaves on the main stem culm of wheat genotypes against thermal units as affected by sowing dates and seasons.

Sowing Dates	Intercept (a)	Slope (b)	Correlation Coefficient (r)
November			
2010/2011	1.293	0.008	0.99
2011/2012	1.418	0.008	0.99
December			
2010/2011	-0.504	0.009	0.99
2011/2012	-0.245	0.009	0.99

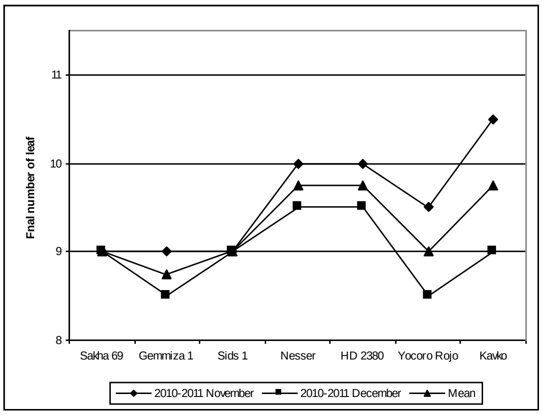
Number of leaves

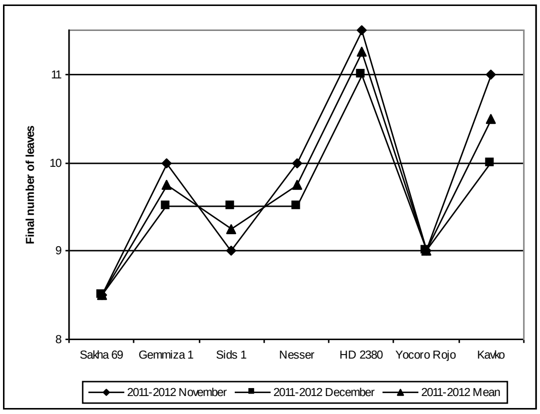
Number of leaves per culm was linearly related to the accumulated degree-days (r=0.99). Cao and Moss, 1989 and Mosaad, 1995 reported that the relationship between the number of leaves on main stem and accumulated degree-days is linear in cereals.

The mean number of leaves ranged from 8.5 to 11.5 (Table 4 and Fig. 2). Differences between season's dates and genotypes were significant and more leaves were produced in 2011/2012, also, December sowing had fewer leaves than the November sowing. Genotypes differed in total number of leaves at anthesis and leaf emergence rates. However, HD 2380 was the highest in final leaves with insignificant different with Kavko, this results agrees with obtained by Cao and Moss, 1991 and Mosaad 1995.

CONCLUSION

In total, on the basis of the results of the study, it can be concluded that linear response was found between rate of leaf appearance and thermal time. Also, genetic constitution of genotypes had larger effect on phyllochron and number of leaves per main-stem than temperature. So, more studies should hold to detect genetic control of phyllochron.





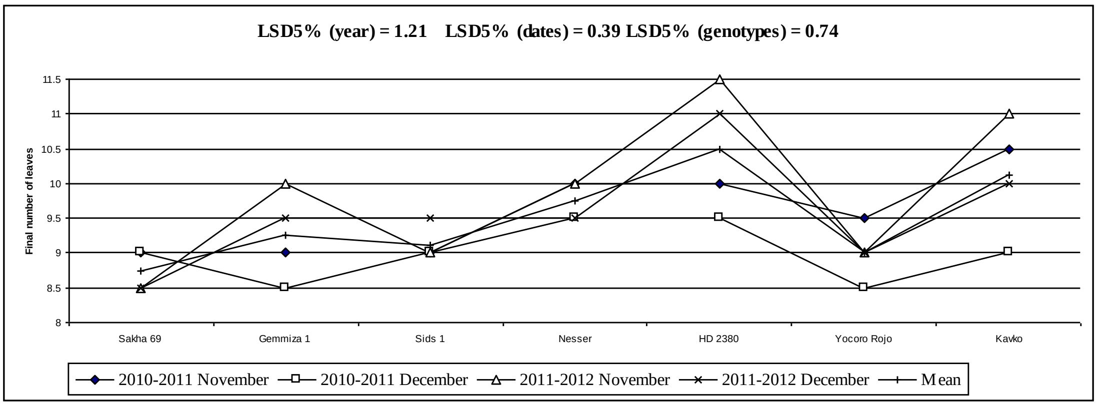


Figure2. Effect of planting dates and seasons on final leaf number of wheat genotypes during 2010/2011 and 2011/2012 seasons.

Table 4. Effect of sowing dates and seasons on final leaf number of wheat genotypes at anthesis during 2010/2011 and 2011/2012 seasons.

Genotypes	2010-2011		2011-2012		Mean
	November	December	November	December	
Sakha 69	9.0	9.0	8.5	8.5	8.75
Gemmeiza 1	9.0	8.5	10.0	9.5	9.25
Sids 1	9.0	9.0	9.0	9.5	9.12
Nesser	10	9.5	10.0	9.5	9.75
HD 2380	10	9.5	11.5	11.0	10.50
Yocoro Rojo	9.5	8.5	9.0	9.0	9.0
Kavko	10.5	9.0	11.0	10.0	10.13
Mean	9.57	9.00	9.85	9.57	9.50
LSD at 5% (dates) = 0.39 , LSD at 5% (genotypes) = 0.74					

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