WHEAT PHASIC DEVELOPMENT UNDER DIFFERENT SOWING WINDOWS UNDER RAINFED CLIMATE

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ABSTRACT

In rainfed areas of Pakistan, erratic rainfall causes variation in sowing window of wheat starting from mid of October and extends until the end of December. The development of wheat plant is a continuity of vegetative phase, reproductive phase and the grain-filling phase. So, to determine the changes in timing of developmental events during the crop-growing season Wheat cultivar, Wafaq-2001, was planted in four sowing windows (22 October, 13 November, 4 December and 24 December) in the field area of National Agricultural Research Centre (NARC), Islamabad. Observations of crop phenology began at the emergence of first leaf and continued until the maturity when yield data was measured. The study revealed that environmental factors play an important role in determining the duration of each phase in the given agro-ecological conditions. The duration of these phases is strongly influenced by the changes in sowing dates. The major components of the environment that affect development are temperature and photoperiod. There are association between sowing window and the yield and also between the duration of phases and yield. So, it becomes important to be able to manipulate the duration of these phases to customize cultivars for specific environments and get the potential yield in a given environment on sustainable basis.

Keywords: Wheat, phasic development,phenology, sowing windows

Introduction

Crop development is a sequence of phenological events controlled by external factors (Landsberg, 1977). These developmental phases controlled by genetics are also affected by environmental factors. The effects of certain environmental factors on crop growth differ depending upon the developmental stages when these factors act. The development of wheat plant is a continuity of vegetative phase, when the leaves are initiated: the reproductive phase, when floret development occurs until the number of fertile florets (the number of grains) is determined; and the grain-filling phase, when the grain first develops the endosperm cells and then grows to determine the final grain weight (Miralles and Slafer, 2000). The duration of each phase is generally determined by interactions between genetic and environmental factors.

Changes in sowing dates can strongly modify the duration of different developmental phases (Hay, 1986). Wheat sown at different dates pass through each developmental stage at slightly different times and, therefore, under different environmental conditions. Thus any one of the developmental stages, which determine the components of yield, could occur under more (or less) favorable conditions. The major components of the environment that affect development are temperature and photoperiod. Temperature has the most significant influence on the rate of leaf appearance and thus the concept of thermal time is frequently used to analyze the dynamics of leaf appearance (Slafer and Rawson, 1997). Nix (1976) showed that although temperature and radiation influence plant processes differently, their combined effects can be usefully described by a photothermal quotient (PTQ) which is the ratio of total solar radiation to the mean daily temperature minus a base temperature. It assumes development rate linearly relates to mean temperature. Many investigators have reported a highly significant linear correlation of leaf number on the main stem of wheat and cumulated degree-days (CDD) (Baker et al., 1980; Klepper 1982; et al., Kirby et al., 1985).

Objectives of this study were to determine the changes in timing of developmental events during the crop-growing season in field-grown plants and determine the effects of major environmental factors controlling the timing and duration of different developmental phases by comparing between crops that were sown in the field at different dates.

Materials and Methods

Wheat cultivar, Wafaq-2001, was planted in four sowing windows in the field at National Agricultural Research Centre, Islamabad (33o 43'N, 73o 06'E and 547 m above sea level). Three 4.5-by-10 m plots per sowing window were sown on 22 October, 13 November, 4 December and 24 December. Row spacing was 15 cm and plant population was 250 plants m-2. 100 kg/ha of N and P (as urea and DAP) was applied. Weed control was done manually. The fields were irrigated whenever the soil surface appeared dry to maintain an adequate water supply.

Observations of crop phenology were made, using Zadok's scale (Zadok, 1974), of ten plants per plot. These measurements began at the emergence of first leaf and continued until the maturity when yield data was measured from each plot and averaged to get the mean.

Weather data (maximum and minimum daily air temperature, rainfall and sunshine hours) was recorded at weather station at National Agricultural Research Centre. Daily growing degree-days (DD) were calculated as:

$$DD = [\{(T_{max} + T_{min}) / 2\} - T_b$$

Where T_{max} and T_{min} are maximum and minimum air temperatures and T_b is a base temperature. We use 5℃ as the base temperature. PTQ was calculated following the algorithm described by Monasterio et al., (1994):

If $T > 10$ $\quad$ PTQ day-1 = solar radiation/ $(T-4.5)$;

If $T \leq 4.5$ $\quad$ PTQ day-1 = 0; and

If $4.5 < T \leq 10.$ $\quad$ PTQ day-1 = solar radiation * $[(T - 4.5 /5.5]/5.5$

Where T is the daily mean temperature $[(max + min)/2]$ and PTQ was expressed as MJm-2 day-1oC-1.

RESULTS AND DISCUSSION

In rainfed areas, erratic rainfall causes variation in sowing window of wheat starting from mid of October and extends until the end of December (Asim et al., 2006). The temperature is high during October that enhances crop growth rates and water requirements. The temperature gradually declines from end of November to December (Table 1). In most of the years, it has been observed that clouds are there but rain does not occur and this situation prevails for several weeks. This impedes crop growth and development due to low irradiant received by the crop during wheat vegetative growing phase. On the other hand, when the wheat crop is at reproductive stage it happened to be sudden raise in ambient temperature during March/April, which causes induced maturity (Fig. 1).

Table1: Average monthly max. and min. temperature, solar radiation, PTQ and rainfall values for Islamabad, Pakistan for wheat-growing periods.

	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May
Max. Temp. (^{0}C)	31.4	26.1	21.2	18.9	20.5	26.9	32.6	38.4
Min. Temp. (^{0}C)	13.9	7.4	3.9	1.5	4.5	9.5	15.1	22.8
Avg. Temp. (^{0}C)	22.6	16.7	12.5	10.2	12.5	18.2	23.8	30.6
Solar Radiations ($MJm^{-2}day^{-1}$)	16.31	13.29	8.99	10.71	11.02	16.43	19.50	23.39
PTQ ($MJm^{-2}day^{-1\,0}C^{-1}$)	0.883	1.065	1.206	1.501	1.285	1.170	0.957	0.980
Rainfall (mm)	22.9	4.1	1.1	17.9	23.9	41.4	10.5	2.9
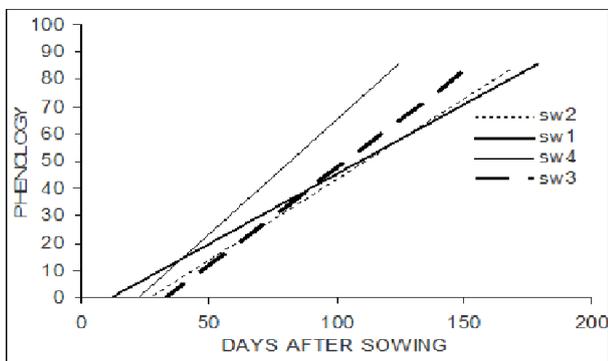
Figure 1: Different Sowing Windows and Duration of Wheat Phenological Stages

Solar radiation provides light required for seed germination, leaf expansion, growth of stem and shoot, flowering, fruiting and thermal conditions necessary for the physiological functions of the plant. Therefore, it is important to understand physiological and morphological behavior in relation to ambient factors, especially temperature and radiation on different developmental phases of wheat crop.

We begin our attempts to uncover the responses of development to environmental factors by looking at the effects of temperature and photoperiod on the duration of the vegetative phase.

Vegetative phase

Changes in the duration of vegetative period associated with sowing dates are largely responsible for changes in crop duration from sowing to harvest. During vegetative period of growth mainly photosynthetic system develops, that is, the leaf and agriculture is a system of exploiting photosynthesis. A study of crop growth is built

on the fact that yield of agricultural plants ultimately depends on the size and efficiency of this photosynthetic system because it serves as the primary source of all energy for humankind. All other crop management practices proceed from this photosynthetic system (Mitchell, 1970). It has been observed (Fig 2 and Table 2) that this photosynthetic system showed declining trend with delayed sowing windows. This may be due to strong vegetative interaction of vegetative period with sowing windows. Hay (1986) also found that the duration of the phase was linearly and negatively associated with the delaying sowing date. So, irrespective of large difference in sowing dates, (Table 2, Sowing windows 1 and 2) the reproductive phase started almost at the same time due to the convergence of development (Fig 2 and Table 2), that is, development progressively accelerated as sowing was delayed (Hay and Kirby, 1991). So, genotype may change their development rate as temperature is changed. Figure 3 demonstrated a linear and negative correlation of temperature and solar radiations on the vegetative period of growth.

Table2: Duration of Wheat Developmental Phases (Days) under different sowing windows

	Sowing Window 1	Sowing Window 2	Sowing Window 3	Sowing Window 4
Vegetative Phase	119	119	111	92
Reproductive Phase	24	12	14	17
Grain Filling Phase	37	37	28	24
Maturity(Days after sowing)	179	168	153	133
Yield (kg/ha)	5280	4300	3410	1970
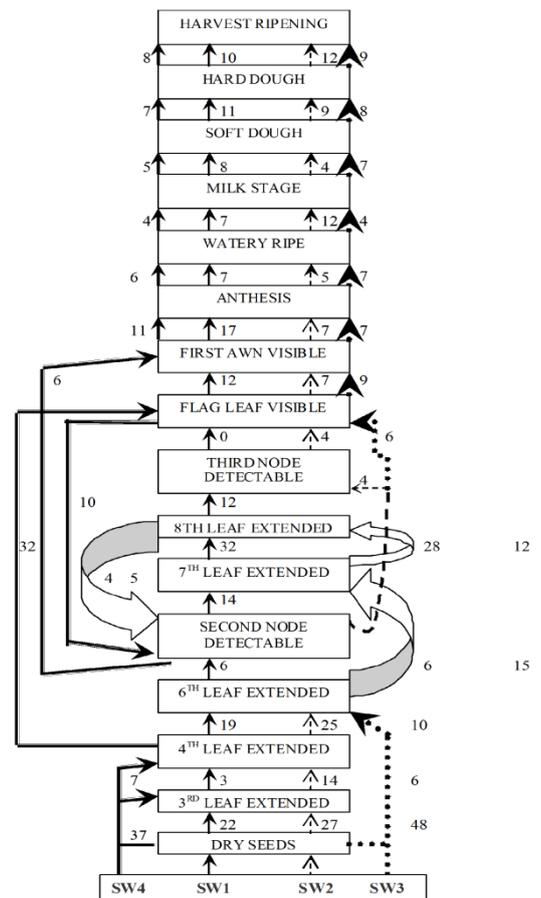
Figure 2: Pattern of Wheat Growth under different Sowing Windows. Numbers show the duration in days between growth stages
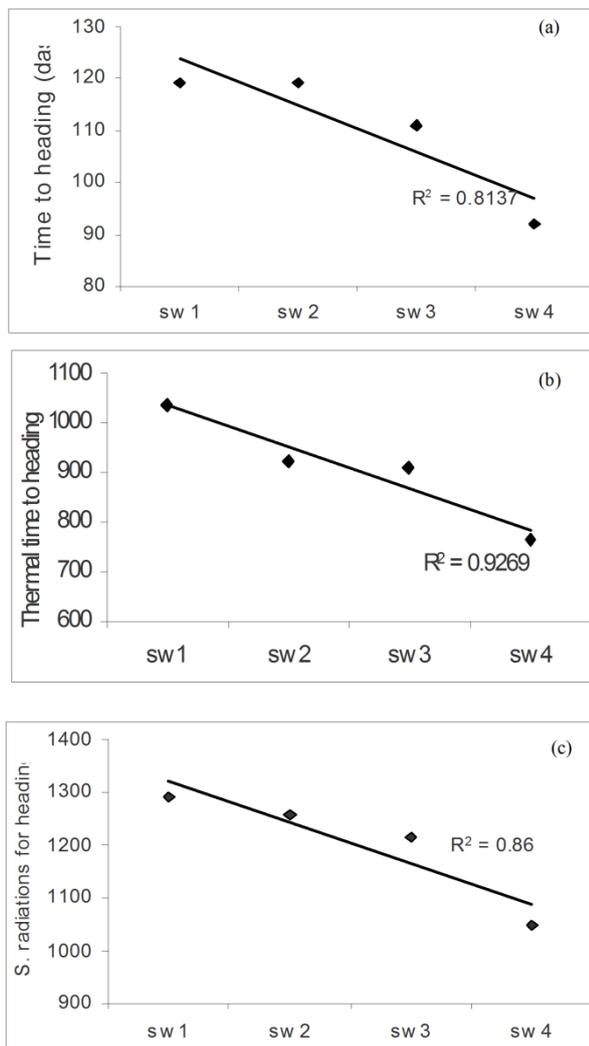
prematurely and to hasten physiological maturity. If the sowing dates are compared for the grain filling duration, there was found a considerable gap for the positive grain filling period among sowing dates. The highest number of days (37 days) for grain filling was taken under sowing window 1 and 2 while sowing window 4 has taken the least number of days (24 days) for grain filling (Fig 6).
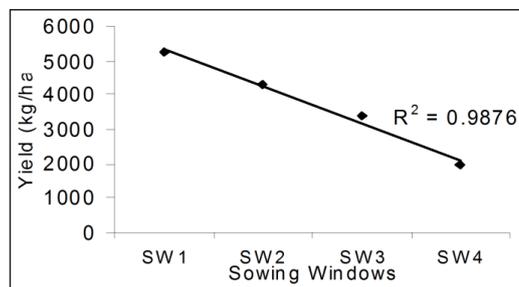

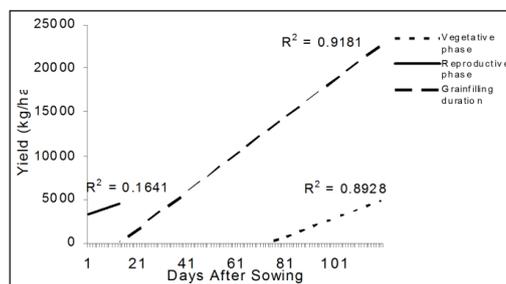**Figure 4: Wheat Yield under different sowing windows**

Figure 5: Wheat yield and duration of different growth phases

Figure 3: Relationship between (a) the times from sowing to heading (b) thermal time required from sowing to heading and (c) solar radiations required for heading and the sowing windows

Reproductive phase

Change in time to heading was more strongly associated with the changes in the duration of the reproductive phase than in the vegetative phase. As the duration of vegetative phase was largely unchanged at each sowing date (Table 2), this result in the exposure of reproductive phase to varying conditions (Angus et al., 1981 and Saini et al., 1986).

There are association between particular developmental stages and the yield components and if, there are association between the duration of phases and yield then it become important to be able to manipulate the duration of these phases to customize cultivars for specific environments. In particular, the duration of sowing to anthesis period has been given flexibility, so that, despite variation in sowing date anthesis can be adjusted to occur at the optimum time foe that location.

Grain-filling phase

Duration of grain filling period has a strong negative response to increasing temperatures. Wiegand and Cuellar (1981) stated that each 1.0ºC increase in mean daily air temperature during the grain filling period of wheat resulted in decreases of 3.1 days and 2.8 mg in grain filling duration and kernel weight, respectively. Increasing temperatures during grain filling tended to stop grain growth
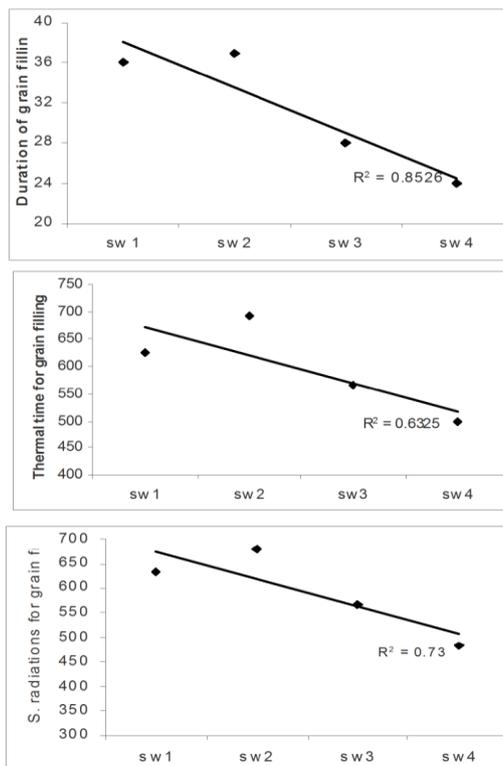

Figure 6: Relationship between (a) the duration of Grain Filling (b) Thermal Time required for grain filling and (c) Solar Radiations required for grain filling and the sowing windows.

These findings are in accordance that of Wiegand and Cullear (1981) who suggested that genetic factors (cultivar) largely determine grain filling rate and environment factors (temperature) largely determines grain filling duration. Here, wheat under fourth sowing window has face quite hard photothermal conditions at the later period of its grain filling. The effects of temperature on grain filling are complex. The duration shortens as temperature increases while the rate of grain filling is not increased by raising the temperature above a range of 21 to 25 ⬚ C.

Yield variation

There are association between sowing window and the yield and also between the duration of phases and yield (Fig 4 & 5). This also shows the importance of sowing time for getting potential yield as depicted by Sial et al, (2010). So, it becomes important to be able to manipulate the duration of these phases to customize cultivars for specific environments. So that, despite variation in sowing date anthesis can be adjusted to occur at the optimum time for that location.

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