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The Modeling of Development Stages of Sunflower on the Basis of Temperature and Photoperiod

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Abstract

This experiment was conducted at the Station of Agricultural Research and Natural Resources, Khoy, Iran in 2007 and 2008 to evaluate the effect of temperature and photoperiod on the duration of development stages of sunflower. A randomized complete block design using a 8 x 3 factorial arrangement with four replications involving eight plantings (29th April, 4th May, 14th May, 24th May, 1st June, 10th June, 19th June and 28th June) and three sunflower cultivars ('Sor', 'Eroflor', 'Azargol'). From the results obtained, all development stages, especially the generative phase were influenced by planting date. The duration of each development stage decreased with the delay in planting. The designed models indicated that the minimum temperature and photoperiod were directly proportional to development rate (DR) the whole life cycle of different sunflower cultivars. DR decreased from emergence (E) to physiological maturity (PM) as day length increased. The relationship between DR and photoperiod could be used as a practical model for estimating E to PM duration of these sunflower cultivars.

Keywords: linear regression, modeling, photoperiod, planting date, sunflower

Introduction

Development, otherwise known as phenology, is considered to be the qualitative variations from emergence to fruit maturity. Temperature and photoperiod are important environmental factors that influence in the development stages of sunflower (Aiken, 2005; Craufurd and Wheeler, 2009).

Previously, Schneither and Miller (1981) reported that the development stages of sunflower are influenced by genetic and environmental conditions. Connor and Hall (1997) introduced the temperature, radiation and photoperiod as the most important environmental factors that have influence on the flowering of sunflowers. Font *et al.* (2008) referred to the contradictory reactions of cultivated sunflowers to day length.

The planting date is one of the most important factors in determining the different development stages of plant growth due to its direct effect on the duration of plant growth period (Unger and Thomson, 1982). The delay in sunflower cultivation decreases the length of the vegetation period (Anderade, 1995) and it also decreases the time needed for the seeds to be filled (Ferreia and Abreu, 2001). Resulting in the reduction of days and cumulated GDD (Goyne *et al*, 1989). These results in the increase of the phonological phases as the plant rapidly evolves (Goyne *et al.*, 1990; Ferreia and Abreu, 2001; Flagelia *et al.*, 2002).

Conflicting results about the response of sunflower reaction in relation to day length duration are abundant in literature. Goyne and Hammer (1982) and Goyne and Schneiter (1987) classified sunflower as a short day plant. However, Khajehpour and Seyedi (2001) and Blamy *et al.* (1997) classified it as an indifferent plant while Rawson and Hindmarsh (1982) and Villalobos *et al.* (1996) classified the plant as a long day plant.

In view of these conflicting reports, this trial was undertaken to evaluate the effect of photo thermal environmental effects on the development stages of different cultivars of sunflower.

Materials and methods

The experiment was carried out during two planting years namely 2007 and 2008 Agricultural Research Station and Natural Resources of Khoy, Iran (Latitude 38°32' North and Longitude of 44°55' East). The height of farm from the sea level is 1157 meters and the average rate of rainfall is 298 mm (Fig. 1).

An 8 x 3 factorial arrangement fitted into a randomized complete block design with four replicates was utilized. Treatments comprised of combinations of eight plantings (29^{th} April, 4^{th} May, 14^{th} May, 24^{th} May, 1^{st} June, 10^{th} June, 19^{th} June and 28^{th} June) with three sunflower cultivars ('Sor', 'Eroflor' and 'Azargol'). Therefore, 24 factorial treatment combinations were obtained. In order to determine the maximum and minimum daily air temperature from the time of planting till harvesting time, some special digital thermometers were installed near the farm.

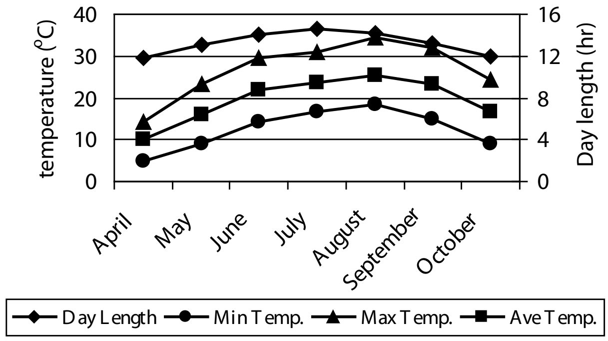

Fig. 1. The average minimum, maximum, mean temperature and photoperiod variation over the two years period

The average day length was calculated for each development stage in hours using the latitude related to the place of experiment. For this calculation, the Keisling (1982) method was used. The development stages of the plant were considered including emergence (VE), becoming star shaped (R1) and physiological maturity (R9) according to Schneither and Miller (1981). The effect of maximum and minimum temperature variables, the average daily temperature, degree of days and day length on the rate of development related to each cultivars in different periods of development, that are vegetation and generative and the whole periods, has been modeled with SPSS version 17 statistical software using the stepwise regression. On this basis the model of development speed that has been proposed by Hammer *et al.* (1982) was used: $1/D = f(t) \times f(p)$

In this model f (t) and f (p) are functions of day length and temperature, respectively and D is the number of days from emergence until flowering.

Results and discussion

The length of vegetation phases terms of the numbers of days and the growing degree days in the first year were much higher in the first than the second year. However the planting dates were the same in both years. The variation could be attributed to the increased average daily temperature which was higher in 2008 than 2007 (Tab. 1). The length of vegetation phase for the 29^{th} April planting had the longest vegetative phase (36.1 days) while the growth period for the 28^{th} June planting had the shortest vegetative phase (26.1 days). This case can itself result in the increase of development rate on the dates of first and second cultivation and also on the dates of seventh and eighth cultivation for such a short day plant like sunflower (Goyne and Schneither, 1987). Other than this, the average daily temperature from the date of first cultivation until the eighth cultivation exhibited an increasing trend. The resultant of the short day and temperature increase causes the increase of vegetation period length in earlier cultivations and causes this period to be short in terms of late cultivation. Garside (1984) showed that the delay in cultivation of different sunflower cultivars causes the period between cultivation and physiological maturation to decrease by 10 to 24 days.

Tab. 1. Comparison of period length of different development stages for different planting dates (day)

Planting Date	Growth Season Length	Reproductive Phase	Vegetative Phase
29^{th} April	100.4 ^{a}	64.50 ^{a}	36.1 ^{a}
4^{th} May	96.9 ^{b}	64.30 ^{a}	32.9 ^{ab}
14^{th} May	94.6 ^{bc}	61.9 ^{cd}	32.5 ^{abc}
24^{th} May	94.0 ^{c}	62.9 ^{b}	30.9 ^{bcd}
1^{th} June	90.1 ^{d}	62.6 ^{bc}	28.8 ^{cd}
10^{th} June	89.8 ^{d}	62.2 ^{bcd}	28.1 ^{d}
19^{th} June	87.2 ^{d}	60.5 ^{d}	26.7 ^{e}
28^{th} June	83.3 e	56.6 ^{e}	26.1 ^{e}

Means with similar letters are not significantly different at 5% level of probability (DMRT).

The length of seasonal growth was longest in 'Azargol' (102.7 days) and shortest in 'Sor' (81.3 days) (Tab. 2). Photo period effects may reduce length of seasonal growth for some of the cultivars, particularly at latitudes less than 40° where double cropping is feasible. This finding corroborated with that of Goyne *et al.* (1990) who had reported similar results.

The model obtained for the two cultivars of 'Azargol' and 'Eroflor' was photothermal. This is an indication that the rate of development is a function of photoperiod and temperature. In the early maturing cultivars of 'Sor', the day length was not used in the model (Tab. 3). Photo period response provides a criterion for optimal planting date while indicating yield limitations caused by the smaller duration of seed fill for a late planted crop (Aiken, 2005).

The negative coefficient of photoperiod shows that the development rate decreased with the increased in the day

Tab. 2. Effects of cultivars on the length of different development stages

Cultivars	Growth Season Length		Reproductive Phase		Vegetative Phase	
	GDD	Day	GDD	Day	GDD	Day
'Azargol'	1561.2 a	102.7 ^{a}	1061.7 ^{a}	70.3^{a}	502.9 ^{a}	33.0 ^{a}
'Eroflor'	1439.6 ^{b}	94.4 ^{b}	950.5 ^{b}	61.2^{b}	488.8 ^{a}	32.9 ^{a}
'Sor'	1259.7 ^{c}	81.2 ^{c}	881.5 ^{c}	56.1 ^{c}	381.5 ^{b}	25.6 ^{b}

Means with similar letters are not significantly different at 5% level of probability (DMRT)

Tab. 3. The linear model of development rate related to vegetation stage of three sunflower cultivars during two experimental years

DR ('Azargol') = 0.86+0.002T_{min}-0.0005DL	r^2=0.979
DR ('Eroflor)' = -0.72+0.003T_{min}-0.0005DL	r^2=*0.986*
DR ('Sor') = 0.001+0.002T_{min}	r^2=0.956

T_{min} = daily minimum temperature, DL = day length, DR=development rate

length and more time is spent for that stage of development to be completed.

The curve for determining the type of relationship of development rate during a vegetation stage with variables being examined showed that for each of the three cultivars, the maximum days positively correlated with the minimum temperature (Fig. 2). Robinson (1971) showed that the length of vegetation development period of sunflower cultivars is not affected by day length. The variations in photoperiod from 14.10 to 15.12 hours during different planting dates coupled with temperature variations are responsible for differences in development rate (Fig. 2). Goyne *et al.* (1990) just used the average daily temperature to predict the time pollination and day length.

The longest reproductive phase (64.50 days) had 29th April and 4th May plantings and the 28th June planting date had the shortest reproductive phase (56.60 days)

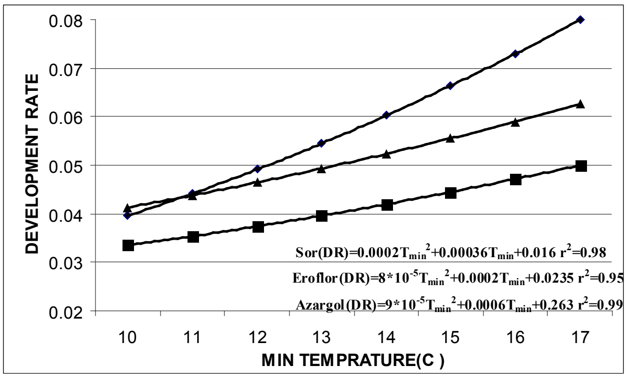

Fig. 2. The relation of development rate of sunflower cultivars with the minimum temperature during vegetation phase

(Tab. 1). Marc and Palmer (1981) considered the R1 stage and the stage of flowering initiation to be separated from each other and Goyne *et al.* (1990) reported that there are photoperiodic reactions in sunflower until the moment of pollination. Based on this, the plant growth during the next development stages, namely R2, R3, and R4, can be affected by photoperiod. So, the effects of photoperiod on the development rate in reproductive stages are not far from expectations in such manner that in the non linear model of each of the three cultivars, the effect of photoperiod was observed in the development rate (Fig. 3). One can attribute this reaction to the relative evolution of plant

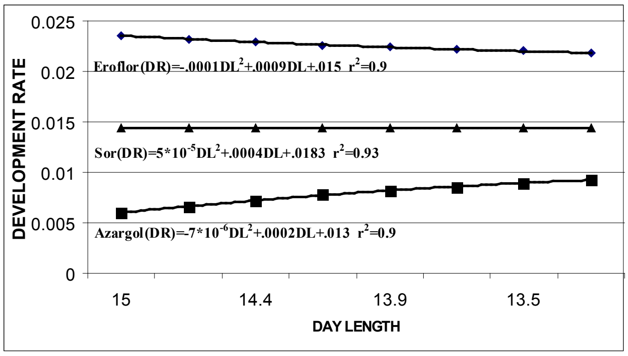

Fig. 3. The relation between development rates of sunflower cultivars with the length of day during the reproductive phase

and the increased sensitiveness of its photo sensors during (on leaf) this period.

In spite of this, photoperiod was not entered in the linear model related to the development rate of the reproductive stage in 'Eroflor' and 'Sor' cultivars (Tab. 4). Massingnam and Angelocci (1993) reported that the development rate from the time of flowering to harvesting had a weak correlation with all registered variables at the time of the experiment.

The cultivars of 'Sor' and 'Azargol' passed this reproductive stage in 56 days and 70 days, respectively (Tab. 2).

The longest growth season length (100.4 days) was obtained with the 29th April planting and the shortest growth period (87.4 days) was obtained with 28th June planting (Tab. 1). Khajehpour and Seyedi (2001) and Ferreia and Abreu (2001) reported the shortening of the growth period in summer planting.

The results obtained here showed that the most important variable influencing the growth period of 'Azargol' is day length. However in 'Eroflor' it is the maximum temperature and in the case of 'Sor', it is the minimum temperature. The entrance of photoperiod in all cultivars was probably affected by the vegetation model (Tab. 5). As we know, the sensitivity to day length in late cultivars was more than in early maturing cultivars. Considering the fact that 'Azargol' had a growth season length of 102.7 days and thus being late maturing, so the day length factor, on its own, could justify its growth period.

The average day length from the first planting date to the eighth planting date had a decreasing trend for each of the three cultivars. A such, the maximum day length of day

Tab. 4. The linear model of development rate of reproductive stage in three sunflower cultivars during two years of experiment

DR (Azargol) = 0.018+0.0001DL+0.0001T_{max}	r^2=0.892**
DR (Eroflor) = -0.015+0.0001T_{max}+ 0.0001T_{min}	r^2=*0.903***
DR (Sor) = -0.06+0.002T_{max}	r^2=0.901**

T_{max} = daily maximum temperature, T_{min} = daily minimum temperature, DL = day length, DR =development rate

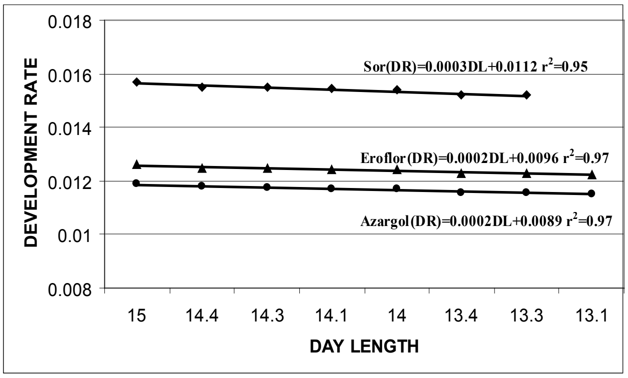

Fig. 4. The relation of development rate of sunflower cultivars photoperiod and the growth season length

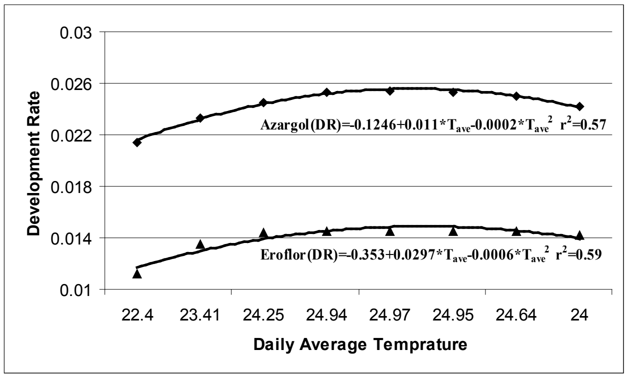

Fig. 5. The non linear relation of the daily average temperature with development rate during growth season length

on the first planting date was 14.55 hours and its minimum amount on the eighth planting was 13.20 hours. Assuming that the sunflower is a short day plant (Doyle, 1975; Goyne and Schneiter, 1987; Khajehpour and Seyedi, 2001) with a delay in planting, day length is decreased and the plant passes the developmental stages more rapidly and maturation occurs early. As it is shown in Fig. 4, with a decrease in day length, the development rate in each of the three cultivars increased significantly (in this case one should not be unaware of the effect of temperature increase). The shortening of developmental stages was a result of temperature increase, as reported by Craufurd and Wheeler (2009) and Goyne *et al.* (1989). Khajehpour and Seyedi (2001) and Goyne and Hammer (1982) reported this shortening of developmental stages as a result of decrease in day length. However, this view was contrary to that of Connor and Sadra (1992) while Dela-Vega (2002) reported that the shortening of development stages was due to the decreased active radiation.

The maximum correlation of daily average temperature with the development rate in 'Azargol' and 'Eroflor' was obtained in a cubic equation as 0.57 and 0.59 respectively. Correlation increase of early ripening 'Sor' in comparison to others might be due to greater effect of temperature on development rate of early ripening cultivars (Fig. 5).

The 'Sor' cultivar (1257.6 GDD) was the earliest maturing type, while 'Azargol' with a growth season length of 102.7 days (and 1561 GDD) was a late maturity plant (Tab. 2). The variation in maturity of sunflower cultivars was reported by Font *et al.* (2008) and Goyne and Schneiter (1988). In this case Doyle (1975) reported that in the region of South Wales Australia, the early maturity types with 1245 GDD of development reach physiological maturity.

Tab. 5. The linear model of development rate during the length of growth period for three cultivars of sunflower

DR (Azargol) = 0.25-0.01DL	r^2=0.914**
DR (Eroflor) = 0.25+6.21x$10^{-5}$$T_{max}$-0.001DL	r^2=0.962**
DR (Sor) = 0.028-0.01DL+0.001T_{min}	r^2=0.958*

T_{max} = daily maximum temperature, T_{min} = daily minimum temperature, DL = day length, DR =development rate

Although sunflower is known as a neutral plant, the results obtained from this research show that day length can be an important factor in adjusting rapidity of development rate in sunflower cultivars during different physiological stages. However, its role in reproductive a development period is not outstanding. It is also better to have a separate model for each cultivar in order to have a more accurate justification of their reactions. It is recommended for future researches to evaluate the amount of absorbed radiation and sunny hours of growth period as an independent variable.

Conclusions

Crop models provide the possibility of anticipating the behavior of plant systems and increase the understanding of their performance. In this study, with delayed sowing, development hastened because the crops encountered higher temperatures during vegetative growth. Although sunflower is known as a neutral plant, the day length can be an important factor in adjusting rapidity of development rate in sunflower cultivars during different physiological stages. However, its role in the reproductive development period is not outstanding. It is also better to have a separate model for each cultivar in order to have a more accurate justification of their reactions. It is recommended for future researches to evaluate the amount of absorbed radiation and sunny hours for the growth period as independent variables.

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