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# Effects of Drought on Morphological Traits of some Sunflower Lines

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**ABSTRACT**

As a summer crop, sunflower is influenced a lot by environmental conditions, so sunflower yield changes frequently year by year. On the other hand, in the recent years' temperatures increased daily or periodically due to global warming. Therefore, new breeding studies should focus mostly to develop sunflower hybrids having high drought tolerance. Based on these priorities, the study was conducted to evaluate the effects of drought stress on plant height, head diameter, flowering and physiological maturity period of some male inbred lines developed previously by Trakya Agriculture Research Institute (TARI). In this study, there were big changes among male lines on tolerance levels of yield traits under controlled conditions to drought. The significant effect of drought stress was determined on head diameter among examined yield traits. However, plant height affected less from drought stress. While head diameter of plants reduced up to 50%, drought stress conditions decreased the days of flowering up to 20% (about one week) of flowering time and about 15% (about 11-12 days) of physiological maturity period. Sunflower lines were screened for improved drought tolerance based on drought factor index (DFI) calculated for head diameter values.

***Keywords:*** Drought tolerance, Inbred lines, Sunflower, Yield traits.

## Introduction

Sunflower (*Helianthus annuus* L.) is one of the most important oil crops and as a summer crop; it grows generally in rainfed regions. In these areas, drought stress is the main limiting factor for sunflower yield and other yield traits. Sunflower plants responses to drought include some processes and changes at morphological, anatomical and molecular levels mostly with decreasing photosynthesis then resulting in yield losses to adapt these stress conditions (Maury *et al*., 1996; 2000; Richard, 1996; 2006; Ali *et al*., 2003; De la Vega *et al*., 2007; Akbari *et al*., 2008; Rauf, 2008; Rauf *et al*., 2009; Hussain *et al*., 2012; Kaya *et al*., 2012; Skoric, 2012; Kaya 2014).

Drought tolerance and seed yield of cultivars are quantitative characters and are strongly influenced by environmental conditions. Therefore, their heritability is complex and these traits are determined largely by G x E conditions in addition to genetic contribution (Yordanov *et al*., 2000; Ali *et al*., 2003; De la Vega *et al*., 2007; Akbari *et al*., 2008; Haddadi *et al*. 2010; Tardieu and Tuberosa, 2010). The effects of drought stress on sunflower yield traits has been evaluated in many studies such as plant height, biological yield, stem diameter, head size, seed number per head, number of leaves per plant, 1000 seed weight, physiological maturity, harvest index, etc. (Razi and Asad, 1998; Yordanov *et al*., 2000; Poormohammad Kiani *et al*., 2007; Nezami *et al*., 2008; Petcu *et al*., 2008; Haddadi *et al*. 2010; 2011; Tardieu and Tuberosa, 2010; Pourtaghi *et al*., 2011; Abdi *et al*., 2012; Boureima *et al*., 2012; Hussain *et al*., 2012; Kaya *et al*., 2012; Skoric, 2012; Kaya 2014).

Due to inadequate stress conditions in the research fields in every year, traditional breeding programs do not work efficiently for accurate selection against drought stress, so significant progress could not be obtained easily. Drought factor index (DFI) also is one of promising indicators among drought indices and use commonly to evaluate plant stress tolerance (Boureima *et al*., 2012). However, modern breeding tools such as molecular marker technologies, QTL, *in vitro* cultures, etc. could make great contribution for drought resistance breeding and significant successful studies are performed recently (Haddadi *et al*., 2011; Abdi *et al*., 2012).

The aim of this study was to determine drought tolerance and to evaluate performance of some yield traits of sunflower male inbred lines developed in National Sunflower project conducted by TARI under controlled stress conditions in Edirne, Turkey.

## Materials and Methods

The study was carried out at TARI research fields with fifty male inbred lines originated from different genetic sources in 2014 (Table 1). Trials were conducted with RCBD with one row plots and three replications. Head size (cm), plant height (cm), flowering and physiological maturity duration (days) were observed and measured. Tunca hybrid belonging Limagrain Co was used as control. In each row, there were five plants and the distance between rows was 70 cm and 30 cm within rows. Trials were planted by hand on 29 May and plants were harvested and threshed by hand on 24 September. The rainfall and humidity in 2014 was over longer year averages while average temperatures were the same (Table 2) and daily rainfalls in 2014 (Table 3) and applied irrigations during vegetation period are given Table 4. On the other hand, chemical and physical properties of soil in the experiment field are given Table 5 and 6, respectively.

Drought Factor Index of inbred lines was calculated as DFI =Log ($S_3$) + 2 X Log ($S_2$) + 4 X Log ($S_1$) (Boureima *et al*., 2012). Tolerance Index (TI) of sunflower genotypes at three levels were calculated as TI (%) = (Droght Stress – Control) / [1 - (Control/100)] X 100 (Glerum, 1985). Drip irrigation was applied and as covering rain shelters, drought stress conditions were set up like below in the experiments. Stress group 1, 2 and 3 were set up on 23.06.2014, 22.07.2014 and 04.08.2014, respectively. **Control:** All plant water requirement was supplied by drip irrigation (when field capacity reduced until 50%); **Stress group 1 ($S_1$):** When plants were 50 cm, **Stress group 2 ($S_2$):** at bud development, **Stress group 3 ($S_3$):** at the milky stage.

## Results and Discussion

Many inbred female and restorer (male) lines and $F_1$ hybrids were developed and released both in Turkey and also in some countries by TARI in Edirne. Therefore, to determine the level of drought tolerance of inbred lines is so important to develop better and widely adapted sunflower hybrids to plant in different conditions. Based on this study, the changes were observed in four important yield traits among sunflower restorer lines against drought stress under controlled conditions.

Plant height was almost not affected from drought stress conditions in the study (Table 7 and Figure 1). However, while there were observed increase at 1st stress, there were some decreases at 2nd and 3rd stress conditions. On the other hand, head size was influenced more from drought stress and they were reduced up to 50% (Table 8 and Figure 2).

The number of 20, 9, 4, 3, 46, 34, 6 and 50 male lines at $S_1$; 9, 4, 16, 27, 7, 40, 50, 34, 21, 24, and 6 at $S_2$ and 8, 6, 9, 14, 41, 34, 50, 4, and 21 lines affected less at $S_3$ from drought stress based on tolerance index of sunflower genotypes. The drought stress conditions reduced flowering time until 20% (about one week). The lines numbered as 8, 22, 43 and 24 at $S_1$ and 8, 22, 32, 9 and 13 influenced less at $S_2$ conditions but it was less comparing with other yield traits Table 9 and Figure 3). On the other hand, drought stress led their physiological maturity time 11-12 days earlier in male lines (Table 10 and Figure 4). Less affected lines were 40, 39, 2, 36, 41 and 51 at $S_1$ and 2, 40, 28, 41 and 35 at $S_2$ and 2, 33, 15, 29 and 28 at $S_3$ conditions.

## Conclusions

In conclusion, plant head size was more influenced by drought then plant height. Therefore, as a general assessment based on DFI calculated form head size; 9758R and 7820R lines might be propounded more drought tolerant than others examined lines. In this study drought tolerant male inbred lines were identified under controlled conditions so they could be used for the future breeding research to develop tolerant sunflower hybrids.

## Acknowledgment

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Table 1. The evaluated sunflower male inbred lines in the study

| # | Code | # | Code | # | Code | # | Code | # | Code |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 0536 R | 11 | 8129 R | 21 | 9759 R | 31 | 9997-7 R | 41 | TT 212 R |
| 2 | 01001 R | 12 | 8165 R | 22 | 9761 R | 32 | 9999 R | 42 | TT 214 R |
| 3 | 010018 R | 13 | 8267 R | 23 | 9786 R | 33 | 10004-1 R | 43 | TT 216 R |
| 4 | 25712 R | 14 | TT 326 R | 24 | 9889 R | 34 | 10004-2 R | 44 | TT 317 R |
| 5 | 3510 R | 15 | 9487 R | 25 | 9947 R | 35 | TT 119 R | 45 | TT 321 R |
| 6 | 62301 R | 16 | 9702 R | 26 | 9979 R | 36 | TT 135 R | 46 | TT 330 R |
| 7 | 6973 R | 17 | 9753-1 R | 27 | 9987 R | 37 | TT 138 R | 47 | K9 R SN 1 |
| 8 | 70352 R | 18 | 9753-2 R | 28 | 9990 R | 38 | TT 199 R | 48 | 9868 R |
| 9 | 7820 R | 19 | 9753-3 R | 29 | 9992 R | 39 | TT 205 R | 49 | 98920 R |
| 10 | 7887-1 R | 20 | 9758 R | 30 | 9993 R | 40 | TT 207 R | 50 | CL 217 R |

Table 2. Some climatic data of longer years and in 2014 during sunflower growth period

| Months | Max. Average Temp. (ºC) | Average Temp. (ºC) | Min Average Temp. (ºC) | Average Humidity (%) | Rainfall (mm) |
|---|---|---|---|---|---|
| **Longer Years Averages (1954-2013)** | | | | | |
| May | 24.7 | 18.2 | 11.6 | 64.4 | 52.0 |
| June | 29.1 | 22.5 | 15. 4 | 60.1 | 44.7 |
| July | 31.7 | 24.7 | 17.3 | 55.9 | 32.0 |
| August | 31.6 | 24.3 | 17.1 | 56.2 | 23.6 |
| September | 27.1 | 19.8 | 13.3 | 62.2 | 36.8 |
| **2014 year** | | | | | |
| May | 25.0 | 18.6 | 12.5 | 68.7 | 89.0 |
| June | 28.7 | 22.3 | 16.4 | 67.2 | 88.5 |
| July | 31.9 | 25.3 | 18.3 | 61.9 | 97.8 |
| August | 32.8 | 25.6 | 18.7 | 61.0 | 12.7 |
| September | 26.5 | 19.6 | 14.5 | 71.4 | 105.3 |

Table 3. Daily rainfalls during the study (mm)

| May | Rainfall | June | Rainfall | July | Rainfall | August | Rainfall |
|---|---|---|---|---|---|---|---|
| 31 May | 28,0 | 4 June | 38,7 | 4 July | 0,9 | 7 August | 11,2 |
| | | 5 June | 6,6 | 5 July | 0,3 | 18 August | 5,6 |
| | | 6 June | 2,2 | 16 July | 39,5 | | |
| | | 26 June | 42,2 | 17 July | 40,1 | | |
| | | | | 20 July | 3,0 | | |

Table 4. Irrigation amounts applied in the experiment plots (mm)

| Irrigation time | Irrigation amounts (mm) | Irrigation time | Irrigation amounts (mm) |
|---|---|---|---|
| 10.06.2014 | 50 mm | 10.08.2014 | 75 mm |
| 25.06.2014 | 70 mm | 18.08.2014 | 60 mm |
| 10.07.2014 | 65 mm | 28.08.2014 | 60 mm |
| 25.07.2014 | 40 mm | | |

Table 5. Chemical properties of soil in the experiment field

| Soil Depth (cm) | Saturation (%) | Total Salinity (%) | pH | $CaCO_3$ (%) | $P_2O_5$ (kg/da) | $K_2O$ (kg/da) | Organic Matter (%) |
|---|---|---|---|---|---|---|---|
| 0-20 | 45 | 0,06 | 6,82 | 1,0 | 15,7 | 61,0 | 1,16 |
| 20-40 | 48 | 0,06 | 6,91 | 1,1 | 17,3 | 64,4 | 1,02 |

Table 6. Physical properties of soil in the experiment field

| Soil Depth (cm) | Soil texture | | | Soil Depth (cm) | Volume Weight (gr/cm³) | Field Capacity | | Wilting Point | | Available water holding capacity | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | % clay | % silt | % sand | | | % | (mm) | % | (mm) | % | (mm) |
| 0-20 | 18.7 | 16.6 | 64.5 | 0-30 | 1,68 | 16,21 | 81,69 | 8,23 | 41,48 | 7,98 | 40,22 |
| 20-40 | 25.0 | 20.8 | 54.2 | 30-60 | 1,71 | 18,78 | 96,34 | 10,12 | 51,92 | 8,66 | 44,42 |
| | | | | 60-90 | 1,58 | 22,84 | 108,26 | 14,23 | 67,45 | 8,61 | 40,81 |
| | | | | 90-120 | 1,54 | 19,47 | 89,95 | 12,79 | 59,09 | 6,68 | 30,86 |
| | | | | 0-90 | | | 286,29 | | 160,85 | | 125,45 |

Table 7. The effect of drought stress on plant heights (cm) in sunflower

| # | Name of Line | Control | Stress 1 | Tolerance Index (%) | Stress 2 | Tolerance Index (%) | Stress 3 | Tolerance Index (%) |
|---|---|---|---|---|---|---|---|---|
| 23 | 9786 R | 90,00 | 108,33 | 120,4 | 87,33 | 97,0 | 85,00 | 94,4 |
| 47 | K9 R SN 1 | 146,00 | 162,67 | 111,4 | 133,67 | 91,6 | 136,67 | 93,6 |
| 26 | 9979 R | 128,33 | 141,33 | 110,1 | 121,33 | 94,5 | 123,33 | 96,1 |
| 33 | 10004-1 R | 107,33 | 118,00 | 109,9 | 102,00 | 95,0 | 111,00 | 103,4 |
| 3 | 010018 R | 127,00 | 139,00 | 109,4 | 124,00 | 97,6 | 126,00 | 99,2 |
| 11 | 8129 R | 131,00 | 143,33 | 109,4 | 127,33 | 97,2 | 128,33 | 98,0 |
| 18 | 9753-2 R | 95,33 | 103,67 | 108,7 | 90,33 | 94,8 | 92,67 | 97,2 |
| 24 | 9889 R | 117,00 | 127,00 | 108,5 | 107,00 | 91,5 | 112,67 | 96,3 |
| 38 | TT 199 R | 139,00 | 149,67 | 107,7 | 136,33 | 98,1 | 138,67 | 99,8 |
| 37 | TT 138 R | 112,00 | 120,67 | 107,7 | 99,67 | 89,0 | 101,33 | 90,5 |
| 29 | 9992 R | 124,00 | 131,67 | 106,2 | 114,00 | 91,9 | 119,33 | 96,2 |
| 48 | 9868 R | 156,33 | 165,00 | 105,5 | 145,33 | 93,0 | 142,00 | 90,8 |
| 34 | 10004-2 R | 96,67 | 101,33 | 104,8 | 91,00 | 94,1 | 95,00 | 98,3 |
| 19 | 9753-3 R | 96,33 | 101,00 | 104,8 | 84,67 | 87,9 | 87,33 | 90,7 |
| 16 | 9702 R | 105,00 | 109,67 | 104,4 | 91,33 | 87,0 | 95,67 | 91,1 |
| 4 | 25712 R | 115,67 | 120,67 | 104,3 | 122,00 | 105,5 | 120,67 | 104,3 |
| 21 | 9759 R | 133,00 | 138,33 | 104,0 | 132,33 | 99,5 | 132,00 | 99,2 |
| 27 | 9987 R | 127,00 | 132,00 | 103,9 | 124,67 | 98,2 | 121,33 | 95,5 |
| 39 | TT 205 R | 120,00 | 124,67 | 103,9 | 105,67 | 88,1 | 111,00 | 92,5 |
| 51 | Tunca (S) | 175,67 | 182,00 | 103,6 | 164,33 | 93,5 | 167,33 | 95,3 |
| 17 | 9753-1 R | 100,00 | 103,00 | 103,0 | 97,67 | 97,7 | 93,33 | 93,3 |
| 2 | 01001 R | 124,33 | 127,33 | 102,4 | 123,33 | 99,2 | 120,33 | 96,8 |
| 10 | 7887-1 R | 128,33 | 131,33 | 102,3 | 122,00 | 95,1 | 122,33 | 95,3 |
| 5 | 3510 R | 140,67 | 143,67 | 102,1 | 135,00 | 96,0 | 134,00 | 95,3 |
| 31 | 9997-7 R | 144,67 | 147,00 | 101,6 | 127,00 | 87,8 | 132,33 | 91,5 |

*Continuing table 7*

| # | Name of Line | Control | Stress 1 | Tolerance Index (%) | Stress 2 | Tolerance Index (%) | Stress 3 | Tolerance Index (%) |
|---|---|---|---|---|---|---|---|---|
| 46 | TT 330 R | 112,33 | 113,67 | 101,2 | 108,33 | 96,4 | 111,33 | 99,1 |
| 32 | 9999 R | 110,67 | 112,00 | 101,2 | 107,00 | 96,7 | 108,67 | 98,2 |
| 15 | 9487 R | 126,00 | 127,33 | 101,1 | 117,00 | 92,9 | 119,67 | 95,0 |
| 43 | TT 216 R | 137,67 | 138,67 | 100,7 | 125,33 | 91,0 | 130,33 | 94,7 |
| 14 | TT 326 R | 127,00 | 127,67 | 100,5 | 120,33 | 94,8 | 119,00 | 93,7 |
| 35 | TT 119 R | 141,33 | 142,00 | 100,5 | 129,33 | 91,5 | 132,00 | 93,4 |
| 36 | TT 135 R | 133,33 | 133,33 | 100,0 | 125,67 | 94,3 | 130,67 | 98,0 |
| 28 | 9990 R | 158,00 | 157,33 | 99,6 | 147,67 | 93,5 | 145,00 | 91,8 |
| 6 | 62301 R | 158,33 | 157,00 | 99,2 | 150,67 | 95,2 | 147,33 | 93,1 |
| 25 | 9947 R | 138,33 | 136,67 | 98,8 | 132,67 | 95,9 | 136,00 | 98,3 |
| 44 | TT 317 R | 161,00 | 159,00 | 98,8 | 143,33 | 89,0 | 147,33 | 91,5 |
| 41 | TT 212 R | 142,00 | 139,67 | 98,4 | 127,33 | 89,7 | 129,67 | 91,3 |
| 8 | 70352 R | 122,00 | 119,00 | 97,5 | 114,33 | 93,7 | 115,67 | 94,8 |
| 40 | TT 207 R | 149,00 | 145,33 | 97,5 | 128,00 | 85,9 | 135,67 | 91,1 |
| 22 | 9761 R | 117,67 | 114,33 | 97,2 | 110,33 | 93,8 | 114,67 | 97,5 |
| 12 | 8165 R | 148,00 | 143,67 | 97,1 | 137,33 | 92,8 | 131,00 | 88,5 |
| 42 | TT 214 R | 132,00 | 128,00 | 97,0 | 114,33 | 86,6 | 112,00 | 84,8 |
| 45 | TT 321 R | 115,00 | 111,33 | 96,8 | 108,67 | 94,5 | 106,00 | 92,2 |
| 20 | 9758 R | 170,33 | 163,00 | 95,7 | 160,33 | 94,1 | 157,67 | 92,6 |
| 9 | 7820 R | 127,67 | 122,00 | 95,6 | 123,00 | 96,3 | 123,33 | 96,6 |
| 1 | 0536 R | 123,33 | 116,00 | 94,1 | 128,33 | 104,1 | 124,00 | 100,5 |
| 30 | 9993 R | 129,33 | 120,00 | 92,8 | 125,00 | 96,6 | 122,33 | 94,6 |
| 7 | 6973 R | 141,00 | 126,00 | 89,4 | 121,33 | 86,1 | 126,00 | 89,4 |
| 50 | CL 217 R | 130,67 | 113,67 | 87,0 | 119,33 | 91,3 | 121,00 | 92,6 |
| x̄: LSD 0,01):1,81 | | 130,3 B | 132,2 A | | 121,9 C | | 123,2 C | |

Table 8. The effect of drought stress on head size (cm) in sunflower

| # | Name of Line | Control | Stress 1 | Tolerance Index (%) | Stress 2 | Tolerance Index (%) | Stress 3 | Tolerance Index (%) |
|---|---|---|---|---|---|---|---|---|
| 20 | 9758 R | 10,00 | 10,67 | 106,7 | 8,00 | 80,0 | 8,00 | 80,0 |
| 9 | 7820 R | 13,00 | 11,33 | 87,2 | 12,00 | 92,3 | 12,33 | 94,9 |
| 4 | 25712 R | 11,67 | 9,00 | 77,1 | 10,67 | 91,4 | 10,67 | 91,4 |
| 3 | 010018 R | 14,33 | 11,00 | 76,7 | 12,33 | 86,0 | 13,00 | 90,7 |
| 46 | TT 330 R | 14,00 | 10,67 | 76,2 | 11,33 | 81,0 | 11,67 | 83,3 |
| 34 | 10004-2 R | 12,33 | 9,33 | 75,7 | 11,00 | 89,2 | 11,33 | 91,9 |
| 6 | 62301 R | 13,67 | 10,33 | 75,6 | 12,00 | 87,8 | 13,00 | 95,1 |
| 50 | CL 217 R | 16,00 | 12,00 | 75,0 | 14,33 | 89,6 | 14,67 | 91,7 |
| 25 | 9947 R | 14,67 | 11,00 | 75,0 | 12,00 | 81,8 | 12,33 | 84,1 |
| 33 | 10004-1 R | 14,00 | 10,33 | 73,8 | 11,33 | 81,0 | 12,00 | 85,7 |
| 38 | TT 199 R | 13,33 | 9,67 | 72,5 | 11,67 | 87,5 | 11,67 | 87,5 |
| 24 | 9889 R | 14,33 | 10,33 | 72,1 | 12,67 | 88,4 | 13,00 | 90,7 |
| 41 | TT 212 R | 19,00 | 13,67 | 71,9 | 16,33 | 86,0 | 17,67 | 93,0 |
| 8 | 70352 R | 11,67 | 8,33 | 71,4 | 10,00 | 85,7 | 11,67 | 100,0 |
| 42 | TT 214 R | 16,33 | 11,67 | 71,4 | 14,00 | 85,7 | 13,67 | 83,7 |
| 11 | 8129 R | 11,67 | 8,33 | 71,4 | 9,67 | 82,9 | 10,00 | 85,7 |
| 39 | TT 205 R | 14,00 | 10,00 | 71,4 | 11,00 | 78,6 | 11,67 | 83,3 |
| 49 | 98920 R | 16,00 | 11,33 | 70,8 | 12,67 | 79,2 | 13,67 | 85,4 |
| 7 | 6973 R | 13,67 | 9,67 | 70,7 | 12,33 | 90,2 | 12,00 | 87,8 |
| 1 | 0536 R | 13,67 | 9,67 | 70,7 | 11,33 | 82,9 | 12,33 | 90,2 |
| 21 | 9759 R | 14,67 | 10,33 | 70,5 | 13,00 | 88,6 | 13,33 | 90,9 |
| 26 | 9979 R | 14,67 | 10,33 | 70,5 | 12,67 | 86,4 | 13,33 | 90,9 |
| 35 | TT 119 R | 14,67 | 10,33 | 70,5 | 12,00 | 81,8 | 12,33 | 84,1 |
| 27 | 9987 R | 19,00 | 13,33 | 70,2 | 17,33 | 91,2 | 17,00 | 89,5 |
| 12 | 8165 R | 15,33 | 10,67 | 69,6 | 13,00 | 84,8 | 12,67 | 82,6 |

*Continuing table 8*

| # | Name of Line | Control | Stress 1 | Tolerance Index (%) | Stress 2 | Tolerance Index (%) | Stress 3 | Tolerance Index (%) |
|---|---|---|---|---|---|---|---|---|
| 31 | 9997-7 R | 14,67 | 10,00 | 68,2 | 11,33 | 77,3 | 12,00 | 81,8 |
| 36 | TT 135 R | 13,33 | 9,00 | 67,5 | 11,00 | 82,5 | 11,33 | 85,0 |
| 51 | Tunca (S) | 20,00 | 13,33 | 66,7 | 17,33 | 86,7 | 18,00 | 90,0 |
| 13 | 8267 R | 14,00 | 9,33 | 66,7 | 10,67 | 76,2 | 11,67 | 83,3 |
| 32 | 9999 R | 11,00 | 7,33 | 66,7 | 8,00 | 72,7 | 8,67 | 78,8 |
| 23 | 9786 R | 15,67 | 10,33 | 66,0 | 13,67 | 87,2 | 13,00 | 83,0 |
| 43 | TT 216 R | 15,67 | 10,33 | 66,0 | 13,33 | 85,1 | 14,00 | 89,4 |
| 17 | 9753-1 R | 14,67 | 9,67 | 65,9 | 12,67 | 86,4 | 12,67 | 86,4 |
| 30 | 9993 R | 11,67 | 7,67 | 65,7 | 9,67 | 82,9 | 10,33 | 88,6 |
| 16 | 9702 R | 15,33 | 10,00 | 65,2 | 14,00 | 91,3 | 13,67 | 89,1 |
| 14 | TT 326 R | 14,33 | 9,33 | 65,1 | 11,33 | 79,1 | 13,33 | 93,0 |
| 10 | 7887-1 R | 10,33 | 6,67 | 64,5 | 8,67 | 83,9 | 9,00 | 87,1 |
| 2 | 01001 R | 14,67 | 9,33 | 63,6 | 11,00 | 75,0 | 12,67 | 86,4 |
| 37 | TT 138 R | 13,67 | 8,67 | 63,4 | 11,00 | 80,5 | 10,67 | 78,0 |
| 19 | 9753-3 R | 14,33 | 9,00 | 62,8 | 11,67 | 81,4 | 12,33 | 86,0 |
| 40 | TT 207 R | 19,67 | 12,33 | 62,7 | 17,67 | 89,8 | 17,33 | 88,1 |
| 47 | K9 R SN 1 | 19,33 | 12,00 | 62,1 | 15,33 | 79,3 | 16,00 | 82,8 |
| 44 | TT 317 R | 20,33 | 12,33 | 60,7 | 16,67 | 82,0 | 16,33 | 80,3 |
| 5 | 3510 R | 9,33 | 5,67 | 60,7 | 6,67 | 71,4 | 7,33 | 78,6 |
| 48 | 9868 R | 14,67 | 8,67 | 59,1 | 11,33 | 77,3 | 12,00 | 81,8 |
| 28 | 9990 R | 13,00 | 7,67 | 59,0 | 10,33 | 79,5 | 11,33 | 87,2 |
| 15 | 9487 R | 15,33 | 8,67 | 56,5 | 11,67 | 76,1 | 12,00 | 78,3 |
| 18 | 9753-2 R | 16,67 | 8,67 | 52,0 | 14,00 | 84,0 | 14,00 | 84,0 |
| 22 | 9761 R | 17,33 | 8,33 | 48,1 | 13,33 | 76,9 | 14,33 | 82,7 |
| $\bar{x}$: LSD (0,01):0,3 | | 14,57 A | 9,94 D | | 12,15 C | | 12,62 B | |

Table 9. The effect of drought stress on flowering period (day) in sunflower

| # | Name of Line | Control | Stress 1 | Tolerance Index (%) | Stress 2 | Tolerance Index (%) |
|---|---|---|---|---|---|---|
| 8 | 70352 R | 55,3 | 53,7 | 97,0 | 55,3 | 100,0 |
| 22 | 9761 R | 55,7 | 54,0 | 97,0 | 55,3 | 99,4 |
| 43 | TT 216 R | 58,7 | 56,7 | 96,6 | 57,7 | 98,3 |
| 24 | 9889 R | 60,3 | 58,0 | 96,1 | 59,3 | 98,3 |
| 16 | 9702 R | 60,0 | 57,7 | 96,1 | 58,7 | 97,8 |
| 9 | 7820 R | 59,0 | 56,7 | 96,0 | 58,3 | 98,9 |
| 13 | 8267 R | 55,7 | 53,3 | 95,8 | 55,0 | 98,8 |
| 32 | 9999 R | 58,7 | 56,0 | 95,5 | 58,3 | 99,4 |
| 10 | 7887-1 R | 57,3 | 54,3 | 94,8 | 56,3 | 98,3 |
| 27 | 9987 R | 56,7 | 53,7 | 94,7 | 54,7 | 96,5 |
| 36 | TT 135 R | 54,7 | 51,7 | 94,5 | 54,0 | 98,8 |
| 51 | Tunca (S) | 60,3 | 57,0 | 94,5 | 58,3 | 96,7 |
| 35 | TT 119 R | 59,7 | 56,3 | 94,4 | 58,0 | 97,2 |
| 49 | 98920 R | 63,7 | 60,0 | 94,2 | 61,3 | 96,3 |
| 11 | 8129 R | 61,3 | 57,7 | 94,0 | 60,0 | 97,8 |
| 44 | TT 317 R | 65,7 | 61,7 | 93,9 | 64,0 | 97,5 |
| 18 | 9753-2 R | 53,7 | 50,3 | 93,8 | 52,7 | 98,1 |
| 33 | 10004-1 R | 57,3 | 53,7 | 93,6 | 56,3 | 98,3 |
| 12 | 8165 R | 61,0 | 57,0 | 93,4 | 58,7 | 96,2 |
| 50 | CL 217 R | 64,7 | 60,3 | 93,3 | 62,0 | 95,9 |
| 17 | 9753-1 R | 53,7 | 50,0 | 93,2 | 53,0 | 98,8 |
| 29 | 9992 R | 57,3 | 53,3 | 93,0 | 55,3 | 96,5 |
| 37 | TT 138 R | 56,0 | 52,0 | 92,9 | 54,7 | 97,6 |
| 19 | 9753-3 R | 54,3 | 50,3 | 92,6 | 53,0 | 97,5 |
| 38 | TT 199 R | 56,3 | 52,0 | 92,3 | 54,7 | 97,0 |

*Continuing table 9*

| # | Name of Line | Control | Stress 1 | Tolerance Index (%) | Stress 2 | Tolerance Index (%) |
|---|---|---|---|---|---|---|
| 40 | TT 207 R | 59,0 | 54,3 | 92,1 | 56,7 | 96,0 |
| 31 | 9997-7 R | 60,7 | 55,7 | 91,8 | 58,7 | 96,7 |
| 15 | 9487 R | 61,0 | 56,0 | 91,8 | 58,3 | 95,6 |
| 14 | TT 326 R | 60,7 | 55,7 | 91,8 | 57,7 | 95,1 |
| 42 | TT 214 R | 60,3 | 55,3 | 91,7 | 58,3 | 96,7 |
| 7 | 6973 R | 59,3 | 54,3 | 91,6 | 57,7 | 97,2 |
| 46 | TT 330 R | 59,7 | 54,7 | 91,6 | 58,0 | 97,2 |
| 30 | 9993 R | 63,0 | 57,7 | 91,5 | 60,3 | 95,8 |
| 3 | 010018 R | 57,7 | 52,7 | 91,3 | 55,3 | 96,0 |
| 1 | 0536 R | 64,3 | 58,7 | 91,2 | 62,0 | 96,4 |
| 21 | 9759 R | 59,3 | 54,0 | 91,0 | 57,3 | 96,6 |
| 41 | TT 212 R | 58,7 | 53,3 | 90,9 | 57,7 | 98,3 |
| 39 | TT 205 R | 56,7 | 51,3 | 90,6 | 54,3 | 95,9 |
| 47 | K9 R SN 1 | 59,7 | 54,0 | 90,5 | 57,0 | 95,5 |
| 6 | 62301 R | 65,3 | 59,0 | 90,3 | 61,3 | 93,9 |
| 2 | 01001 R | 64,3 | 58,0 | 90,2 | 60,7 | 94,3 |
| 48 | 9868 R | 61,0 | 55,0 | 90,2 | 57,3 | 94,0 |
| 34 | 10004-2 R | 61,0 | 54,7 | 89,6 | 58,3 | 95,6 |
| 28 | 9990 R | 60,7 | 53,7 | 88,5 | 56,7 | 93,4 |
| 4 | 25712 R | 61,0 | 54,0 | 88,5 | 56,0 | 91,8 |
| 45 | TT 321 R | 61,3 | 54,0 | 88,0 | 57,3 | 93,5 |
| 25 | 9947 R | 63,3 | 55,7 | 87,9 | 58,3 | 92,1 |
| 26 | 9979 R | 64,0 | 56,0 | 87,5 | 59,3 | 92,7 |
| 23 | 9786 R | 61,7 | 53,7 | 87,0 | 58,0 | 94,1 |
| 5 | 3510 R | 61,7 | 52,3 | 84,9 | 55,0 | 89,2 |
| $\bar{x}$: LSD (0,01):0,66 | | 59,7 A | 55,1 C | | 57,5 B | |

Table 10. The effect of drought stress on physiological maturity period (day) in sunflower

| # | Name of Line | Control | Stress 1 | Tolerance Index (%) | Stress 2 | Tolerance Index (%) | Stress 3 | Tolerance Index (%) |
|---|---|---|---|---|---|---|---|---|
| 40 | TT 207 R | 91,7 | 86,0 | 93,8 | 88,3 | 96,4 | 89,7 | 97,8 |
| 39 | TT 205 R | 92,7 | 86,0 | 92,8 | 86,7 | 93,5 | 90,3 | 97,5 |
| 2 | 01001 R | 96,7 | 89,3 | 92,4 | 94,3 | 97,6 | 97,0 | 100,3 |
| 36 | TT 135 R | 87,7 | 80,3 | 91,6 | 84,0 | 95,8 | 85,7 | 97,7 |
| 41 | TT 212 R | 94,3 | 86,3 | 91,5 | 90,7 | 96,1 | 91,0 | 96,5 |
| 51 | Tunca (S) | 101,0 | 92,3 | 91,4 | 93,0 | 92,1 | 98,3 | 97,4 |
| 28 | 9990 R | 95,0 | 86,7 | 91,2 | 91,3 | 96,1 | 93,7 | 98,6 |
| 38 | TT 199 R | 91,3 | 83,0 | 90,9 | 86,3 | 94,5 | 89,7 | 98,2 |
| 37 | TT 138 R | 91,7 | 83,3 | 90,9 | 86,7 | 94,5 | 89,7 | 97,8 |
| 29 | 9992 R | 90,7 | 82,3 | 90,8 | 86,3 | 95,2 | 89,7 | 98,9 |
| 11 | 8129 R | 94,0 | 85,3 | 90,8 | 87,7 | 93,3 | 90,0 | 95,7 |
| 43 | TT 216 R | 93,3 | 84,7 | 90,7 | 89,0 | 95,4 | 91,0 | 97,5 |
| 26 | 9979 R | 99,7 | 90,3 | 90,6 | 94,7 | 95,0 | 98,0 | 98,3 |
| 35 | TT 119 R | 92,3 | 83,3 | 90,3 | 88,7 | 96,0 | 91,0 | 98,6 |
| 22 | 9761 R | 91,7 | 82,7 | 90,2 | 86,3 | 94,2 | 89,3 | 97,5 |
| 48 | 9868 R | 102,0 | 91,3 | 89,5 | 95,3 | 93,5 | 98,7 | 96,7 |
| 3 | 010018 R | 91,7 | 82,0 | 89,5 | 85,3 | 93,1 | 88,7 | 96,7 |
| 4 | 25712 R | 94,3 | 84,3 | 89,4 | 89,3 | 94,7 | 91,0 | 96,5 |
| 49 | 98920 R | 99,3 | 88,7 | 89,3 | 93,7 | 94,3 | 96,3 | 97,0 |
| 24 | 9889 R | 93,7 | 83,7 | 89,3 | 87,3 | 93,2 | 92,0 | 98,2 |
| 46 | TT 330 R | 93,7 | 83,7 | 89,3 | 87,0 | 92,9 | 90,3 | 96,4 |
| 5 | 3510 R | 95,0 | 84,7 | 89,1 | 89,7 | 94,4 | 92,3 | 97,2 |
| 8 | 70352 R | 89,0 | 79,3 | 89,1 | 83,3 | 93,6 | 84,7 | 95,1 |
| 50 | CL 217 R | 99,3 | 88,3 | 88,9 | 94,3 | 95,0 | 97,7 | 98,3 |

*Continuing table 10*

| # | Name of Line | Control | Stress 1 | Tolerance Index (%) | Stress 2 | Tolerance Index (%) | Stress 3 | Tolerance Index (%) |
|---|---|---|---|---|---|---|---|---|
| 30 | 9993 R | 96,3 | 85,7 | 88,9 | 89,3 | 92,7 | 93,3 | 96,9 |
| 32 | 9999 R | 92,7 | 82,3 | 88,8 | 88,7 | 95,7 | 90,3 | 97,5 |
| 16 | 9702 R | 95,3 | 84,7 | 88,8 | 88,7 | 93,0 | 92,0 | 96,5 |
| 42 | TT 214 R | 95,3 | 84,7 | 88,8 | 88,0 | 92,3 | 92,3 | 96,9 |
| 23 | 9786 R | 96,7 | 85,7 | 88,6 | 92,3 | 95,5 | 94,3 | 97,6 |
| 15 | 9487 R | 92,7 | 82,0 | 88,5 | 86,0 | 92,8 | 91,7 | 98,9 |
| 19 | 9753-3 R | 85,7 | 75,7 | 88,3 | 81,3 | 94,9 | 83,7 | 97,7 |
| 9 | 7820 R | 94,3 | 83,3 | 88,3 | 86,7 | 91,9 | 91,3 | 96,8 |
| 47 | K9 R SN 1 | 95,7 | 84,3 | 88,2 | 91,7 | 95,8 | 93,7 | 97,9 |
| 20 | 9758 R | 99,7 | 87,7 | 88,0 | 89,3 | 89,6 | 96,7 | 97,0 |
| 31 | 9997-7 R | 95,7 | 84,0 | 87,8 | 88,3 | 92,3 | 94,3 | 98,6 |
| 10 | 7887-1 R | 92,3 | 80,3 | 87,0 | 83,7 | 90,6 | 87,3 | 94,6 |
| 21 | 9759 R | 94,7 | 82,3 | 87,0 | 84,3 | 89,1 | 91,0 | 96,1 |
| 12 | 8165 R | 94,0 | 81,7 | 86,9 | 86,7 | 92,2 | 91,0 | 96,8 |
| 7 | 6973 R | 94,3 | 81,7 | 86,6 | 84,0 | 89,0 | 88,3 | 93,6 |
| 13 | 8267 R | 93,3 | 80,7 | 86,4 | 83,7 | 89,6 | 90,0 | 96,4 |
| 14 | TT 326 R | 95,3 | 82,3 | 86,4 | 85,0 | 89,2 | 90,7 | 95,1 |
| 45 | TT 321 R | 96,0 | 82,7 | 86,1 | 90,3 | 94,1 | 93,3 | 97,2 |
| 18 | 9753-2 R | 86,3 | 74,0 | 85,7 | 79,7 | 92,3 | 84,7 | 98,1 |
| 44 | TT 317 R | 101,3 | 86,3 | 85,2 | 90,3 | 89,1 | 97,3 | 96,1 |
| 25 | 9947 R | 96,7 | 81,7 | 84,5 | 85,7 | 88,6 | 88,7 | 91,7 |
| 34 | 10004-2 R | 96,3 | 78,7 | 81,7 | 85,3 | 88,6 | 90,7 | 94,1 |
| 33 | 10004-1 R | 94,3 | 74,3 | 78,8 | 90,3 | 95,8 | 93,7 | 99,3 |
| $\bar{x}$: LSD (0,01):0,45 | | 94,4 A | 83,6 D | | 88,1 C | | 91,6 B | |

Figure 1. DFI Index on plant heights of sunflower lines

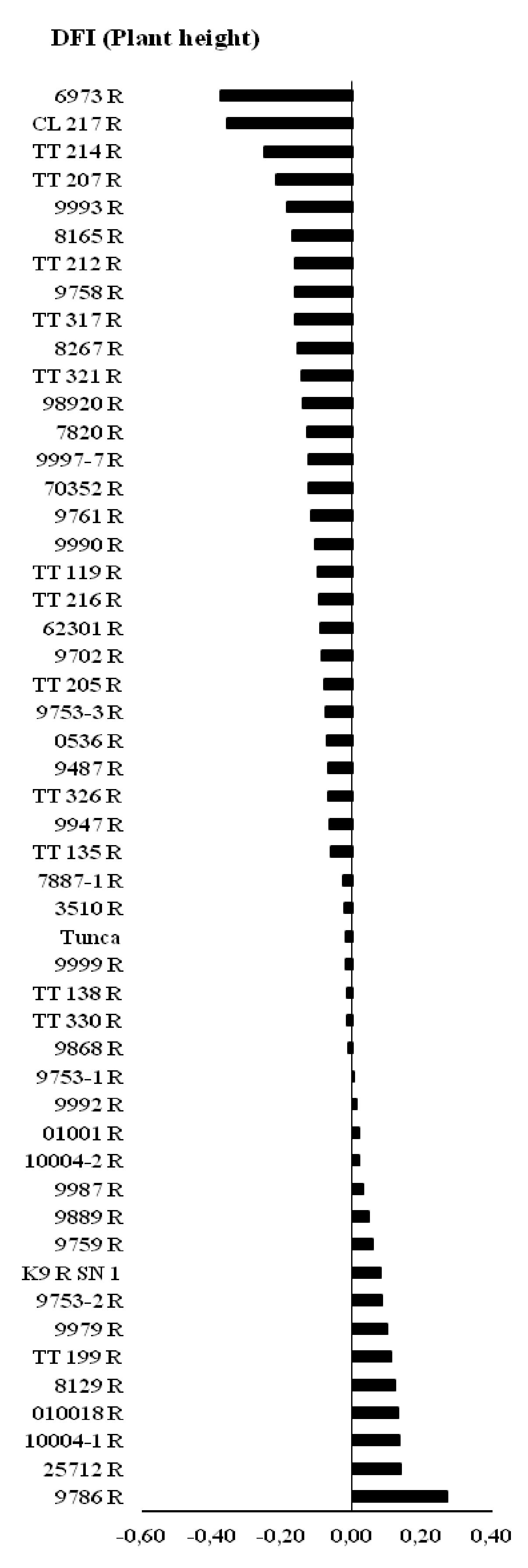



Figure 2. DFI Index on head diameters of sunflower lines

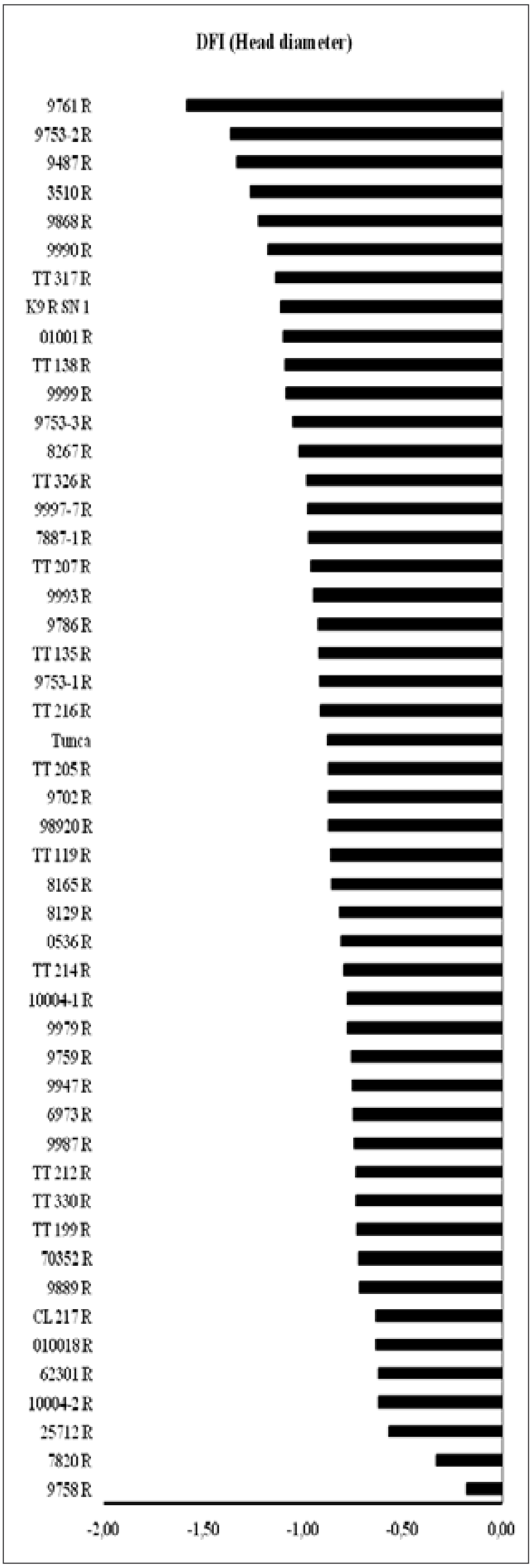


Figure 3. DFI Index on flowering time of sunflower lines

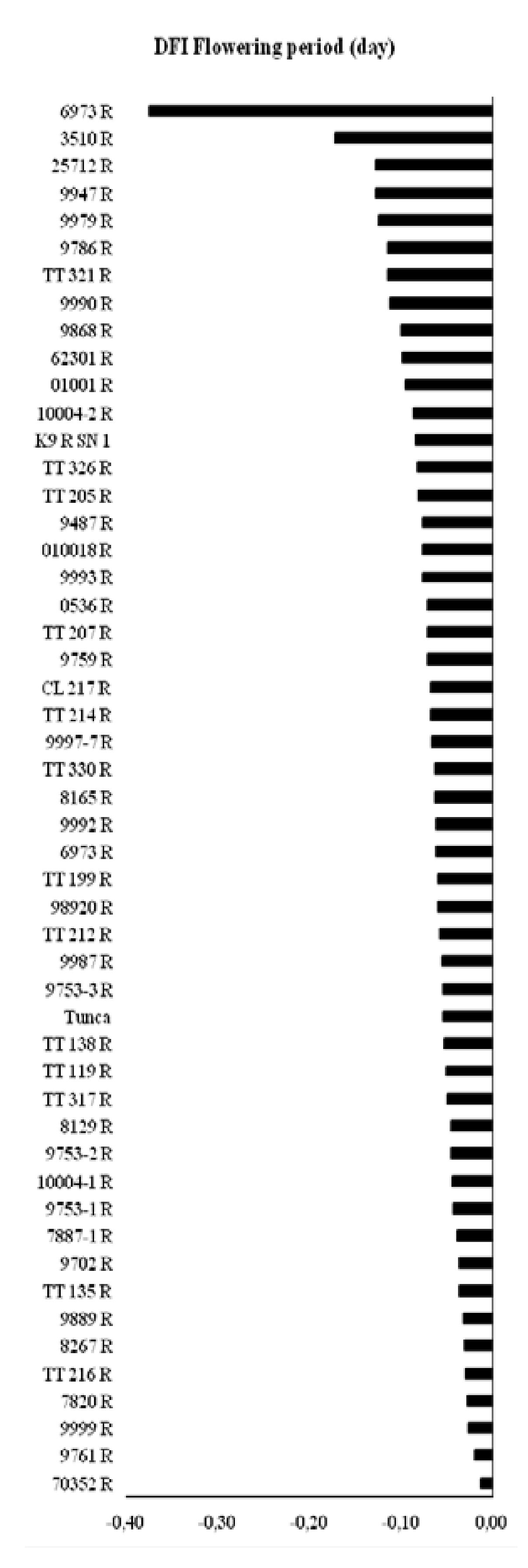
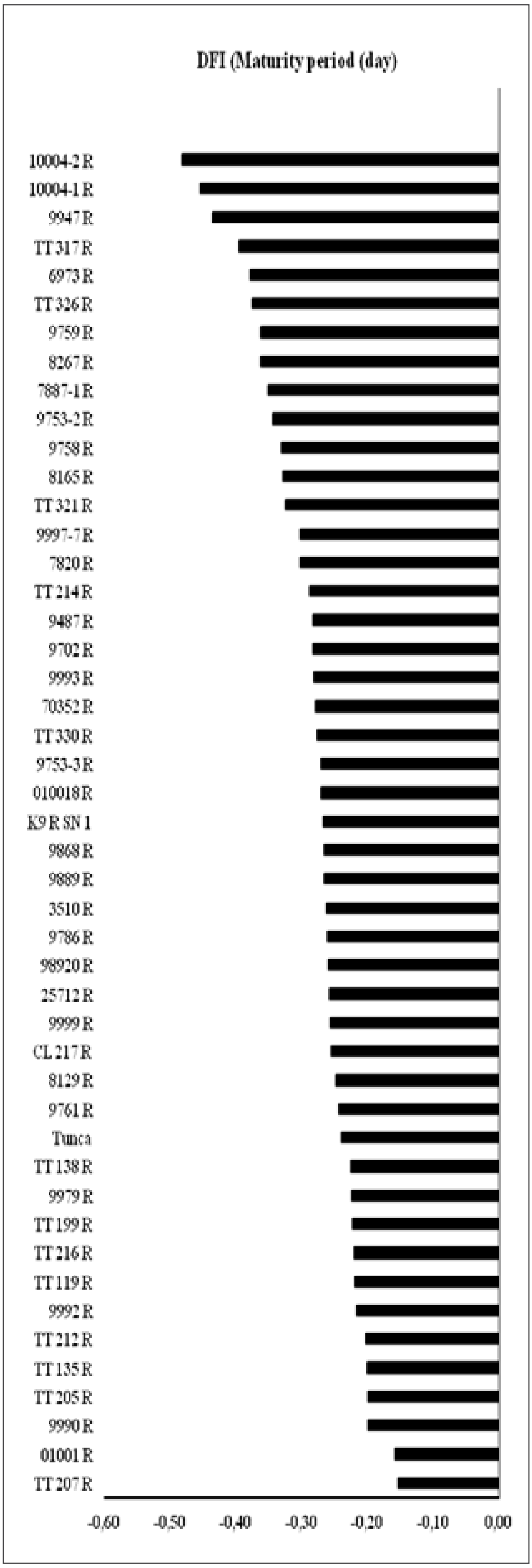



Figure 4. DFI Index on physiological maturity of sunflower lines



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