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Effect of Temperature and Photoperiod on Seedling Emergence of Flax (*Linum usitatissimum* L.)

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Abstract: An experiment to determine the effect of temperature and photoperiod on seedling emergence of flax under controlled environmental conditions was carried out, using the two *Linum usitatissimum* genotypes Windemore and Sarı-85 and 5 temperature (10, 15, 20, 25 and 30°C) and four photoperiod (complete dark, 16 h dark:8 h light, 12 h dark:12 h light and 8 h dark:16 h light) regimes, in all combinations. Total percent seedling emergence and seedling emergence rate of varieties were significantly affected by the variety, temperature and variety×temperature interactions. The overall percent of seedling emergence of Windemore was 29% higher than Sarı-85. The highest emergence of seedlings was obtained at 30°C for both varieties as 96.8% for Windemore and 76.9% for Sarı-85 and further increase in temperature resulted in a gradual increase in seedling emergence. Less than 40 and 30% of seedlings emergence were obtained for Windemore and Sarı-85, respectively, at 10°C. Seedling emergence rate was fastest at 30 and slowest at 10°C. Relatively high percent seedling emergence was obtained in a 12 h dark:12 h light photoperiod in comparison to seedlings emerged in the other photoperiod condition. However the photoperiod did not significantly affected either percent seedlings emergence or seedling emergence rate. Recovery experiment confirm that exposure of seeds to various temperature had significant effect on viability of flax seeds whereas photoperiod had little effect on viability of flax seeds.

Key words: Flax, seedling emergence, temperature, photoperiod

INTRODUCTION

There is considerable interest in increasing the emergence ability of the crops. However, the success in emergence seems to be highly dependent on genotype, seedbed conditions, cultivated treatments and their interactions (Kurt, 2001). The seedbed conditions of soil temperature, oxygen concentration, microorganism, soil structure and water level is important factor affecting the emergence and development of seedlings (Weubker *et al.*, 2001). The relatively minor chemical changes to emergence capacity have been readily manipulated in several crops. So, it has been found that emergence of many plants occur at times when there is an optimal combination of temperature and photoperiod (Naidoo and Naicker, 1992; Gutterman *et al.* 1995).

Research showed that the seedling elongation increases as a temperature increased (Alm *et al.*, 1993). A several study also showed that temperature significantly effected emergence ability of plant genotypes (Specht and Keller, 1997; Herranz *et al.*, 1998; Milberg and Andersson, 1998; Ianucci *et al.*, 2000; Benvenuti *et al.*, 2001; Eileen *et al.*, 2001; Wuebker *et al.*, 2001; Khan and Ungar, 2001; Nyachiro *et al.*, 2002; Anonymous, 2004; Carter *et al.*, 2004; Zia and Khan, 2004)

Photoperiod or changes in day length can also affect emergence. Certain seeds, especially some woody, temperate species require particular day lengths for germination and emergence. Absence of light almost completely inhibits germination and emergence of *Triglochin maritime* L. (Khan and Ungar, 1999) and *Sporobolus indicus* L. (Andrews, 1997) and partially inhibits germination and emergence in *Apium graveolens* L. (Garcia *et al.*, 1995), *Allium staticiforme* Sibth. and Sm., *Brassica tournefortii* Gouan, Cakile maritime Scop. and *Onanthus maritimus* L. (Thanos *et al.*, 1991), while seeds of *Atriplex stocksii* Boiss (Khan and Rizvi, 1994) and *Suaeda fruticosa* fossk. (Khan and Ungar, 1998) are not inhibited by the absence of light.

Flax is one of the oldest crops cultivated by man for its seeds and fibers. All parts of plant have extensive and varied uses. An important consideration for maximizing linseed production is establishing an optimum seedling stand following planting. However the influence of temperature and photoperiod on linseed emergence has not been studied. The aim of the study presented here

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was to determine seedlings emergence and emergence rate of flax (*L. usitatissimum* L. var. Windemore and Sarı-85) under various temperature and light conditions.

MATERIALS AND METHODS

Experiment was performed in temperature and photoperiod controlled growth chamber to study flax seedling emergence using varieties Windemore and Sarı-85. Seeds of these cultivars are yellow in color. The study was carried out in the experimental laboratory of University of Ondokuz Mayis, Faculty of Agriculture at 2004. Seeds were surface sterilized using sodium hypochlorite (0.20%) for 1 min, fallowed by through rinsing with sterile water and air-drying.

Soil compost containing 1 part soil : 1 part sand 1 part manure was gathered from experimental station of Agricultural Faculty in 2004, sieved through a 2 mm mesh screen, air dried to constant weight at 20-23°C (5.6% moisture) and stored in large cans at room temperature for use in the experiment. Sterile soil was prepared by autoclaving twice at 121°C for 90 min and left for 4 days before use.

Fifty seeds per Petri dish (100×100×15 mm) were placed on Watman No. 1 filter paper and the dishes were tight-fitted Eight replicates were used per treatment. Then autoclaved soil was poured into the petri dishes and seeds completely covered by soil. After then sterile distilled water was added to the autoclaved soil on the soil capacity. Petri dishes were covered and wrapped with a strip of Para Film around the edge of the cover to prevent evaporation (Dahlquist, 2004).

A growth chamber with automatic temperature, light and humidity controls was used in all seedling emergence experiments. Temperatures at which emergence was tested were constant 10, 15, 20, 25 and 30°C. A 24 h cycle was used, where all temperatures coincided with a dark (0 h light), 16 h dark : 8 h light period, 12 h dark 12 h light period and 8 h dark : 16 h light period. Light was supplied by Sylvania cool white fluorescent lamps, 25 mol $m^{-2}s^{-1}$ and 400-750 nm.

Seedlings were counted as emerged once the cotyledons appeared above the soil surface. Counting for a particular temperature regime was carried out until none of the treatments showed any new emergence for two successive counts. The days to maximum number of emerged seedlings was recorded on every alternate day for 12 days and percent emergence calculated. Rate of emergence was estimated by using a modified Timos's index of germination volocity, emergence volocity = P/t, where P is the percentage of emergence at 2 days intervals and t is the total emergence period (Khan and Ungar, 1997; Zia and Khan, 2004; Yang *et al*., 2005).

A logid transformation given by $\log_{10}$ [P/(100-P)] (Bartlett, 1947; Mündel *et al*., 1997) was applied to the percentage emergence (P) data to stabilize the variance. These data were analyzed using SPSS for Windows, Version 8.0 (SPSS, 1994). A two-way ANOVA was also used to demonstrate the interaction between various factors affecting the rate and percent seedling emergence. A Bonferroni test was used ($p<0.05$) to determine significant differences between means of percent seedling under various light and temperature regimes.

RESULTS AND DISCUSSION

A two-way ANOVA indicated significant ($p<0.001$) individual effects of variety, temperature and their interaction on percent of seedling emergence and rate of seedling emergence of flax seeds (Table 1).

The overall mean of final percent of seedling emergence of Windemore (82.0%) was obtained 29% higher than Sarı-85 (64.87%). Exposure to different photoperiods resulted in a gradual change in percent emergence and this change varied with the change in temperature. Maximum seedling emergence was obtained in both varieties as 98.0% for windemore and 80.1% for Sarı-85 at 30°C under 12 h dark:12 h photoperiod (Fig. 1). Although the best seedling emergence under different photoperiods was observed at 30°C in both varieties, 25°C was not significantly different from 30°C. At the lower three temperatures of 10, 15 and 20°C, a significantly low percent seedling emergence was recorded. Further decrease in temperature decreased seedling emergence and seedling emergence at 10°C was comparatively lower than emergence at the other temperature under the all different photoperiods. Exposure to lower (10°C) temperature substantially inhibited seedling emergence in all photoperiods (Fig. 1) and the lowest seedling emergence was obtained at 10°C, where 37.1% (Windemore) and 29.4% (Sarı-85) and seedling emergence was obtained in complete dark condition.

The percent seedling emergence from lowest to highest temperature in both varieties was changed between 38.1 to 96.8% in Windemore and 29.8 to 76.9% in Sarı-85. The percent seedling emergence increased with a depending increasing temperature. So that, our experiment results indicated about 2.5 fold percent seedling emergence between the highest and the lowest seedling emergence temperature. This is very important to

Table 1: A two-way ANOVA of the effects of variety (V), temperature (T) and their interaction on emergence of flax

Dependent variable	V	T	V×T
Seedling emergence (%)	1453.4***	1967.3***	25.3***
Rate of seedling emergence	1343.9***	2008.1***	25.4 ***

Note: Numbers indicate F-values (***, p<0.001)

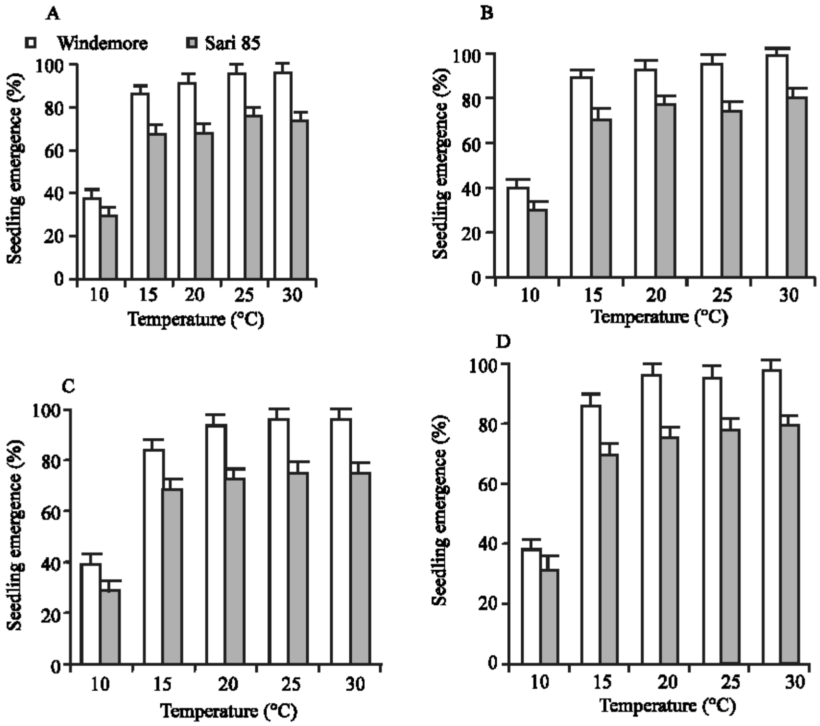

Fig. 1: Mean final percent seedling emergence of *Linum usitatissimum* L. var. Windemore and Sarı-85 in various temperature and photoperiod condition. a) complete dark; b) 12 h dark: 12 h light; c) 16 h dark:8 light and d) 8 h dark:16 h light. Bars represent mean±SE

establish of optimum plant density in field. In our region (Back Sea Region in Turkey), flax sowing season occurs in late autumn (from Sep. to Oct.) and late spring (from Apr. to May) and temperature during this period are low, which would favor the germination and seedling establishment of flax. The optimum temperatures determined in this study showed that winter and summer sowing period in Samsun may be taken August to September rather than September to October and summer sowing period May to June rather than April to May to good establishment of flax.

This present experiment demonstrated that Windemore have 29% higher seedling emergence than Sarı-85. On average, the seed size of Windemore was larger than Sarı-85. In previous, the successfully experiment with linseed also indicated different emergence percentages (Gupta and Basak, 1983; O'Connor and Gusta, 1994). O'Connor and Gusta (1994) demonstrated that large seed size of varieties has a higher percent emergence than the small seed size of cultivars. Gupta and Basak (1983) also found that large-seeded flax varieties germinated and emerged earlier than small-seeded varieties.

Temperature also affected speed of seedling emergence (Table 1). The maximum seedling emergence of both varieties in the different photoperiod was obtained first 8 days under all temperature condition. Figure 2 shows the mean results of the temperature effects in different photoperiod conditions. At 10°C, although seedling emergence generally increased significantly with longer seedling emergence period, it never exceeded 40% for Windemore and 30% for Sarı-85. The seedling emergence process was very slow at 10°C, less than 25% for windemore and 20% for Sarı-85 at 6 days and maximum percent seedling emergence reached at 8 days for both varieties in all photoperiod condition. At 30°C, at least half of the seedling emerged by 6 days for Windemore and by 8 days for Sarı-85, regardless of photoperiod. However there was no statistically different between 25 and 30°C for daily seedling emergence. Over all temperatures, the greatest increase in percent of seedling emergence was usually observed between the 4 and 6 days incubations. The rate of seedling emergence reached about 85% for Windemore and 70% for Sarı-85 at 15°C then after slowly increased and reached maximum at 30°C in both varieties in all photoperiod conditions. The range analysis showed that the optimum temperature for seedling emergence lies between 25 and 30°C with a predicted seedling emergence rate close to 90% (Windemore) and 75% (Sarı-85) or more after 6-8 days of incubation.

The rate of seedling emergence provides a more accurate picture of how a cultivar responds in to temperature. The final seedling emergence for the two

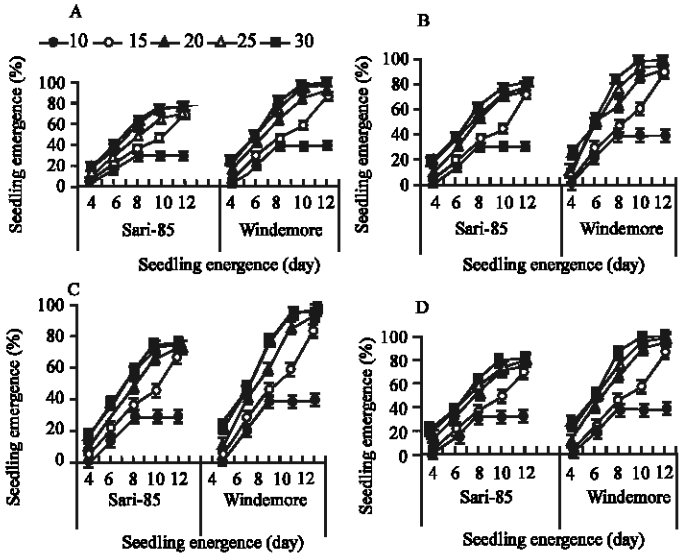

Fig. 2: Cumulative mean percent seedling emergence of *Linum usitatissimum* L. var. Windemore and Sarı-85 seeds over time in 10, 15, 20, 25 and 30°C temperature in a) complete dark; b) 12 h dark:12 h light; c) 16 h dark: 8 h light and d) 8 h dark:16 h light photoperiod. Bars represent mean±SE

varieties arranged from 33.9 to 86.9% with a overall mean of 73.34%. The highest percent seedling emergence (86.9%) recorded at temperature of 30°C and the lowest percent seedling emergence (33.9%) was recorded at temperature of 10°C. The germination and seedling emergence involve an initial imbibitions phase followed by an active growth phase. Rapid water uptake occurs during the first days followed by a slow water uptake which is related to the active growth phase (Schopfer and Plachy, 1984). Liptay and Schopfer (1983) demonstrated that the difference in the ability of two tomato lines to germinate at 10°C was due to their water status. Lafond and Baker (1986) reported temperature had a significant effect on water uptake between 10 and 20°C in wheat. Abscisic acid, a well known inhibitor of seed germination and seedling emergence, inhibits water uptake in *Brassica napus* seeds (Schopfer and Plachy, 1984). Since flax seeds have a waxy seed coat and a mucilage layer, it would not be too surprising that water uptake would be restricted at the lower temperatures. There was no attempt in this study to correlate either water uptake or abscisic acid levels with the ability of flax cultivars to germination and seedling emergence at the lower temperatures.

Present results indicated that increased temperature was increased percent seedling emergence. The evidence thus suggests that seedling emergence may be influenced by seedling emergence temperature. However, the magnitude of the effect in flax was small and unlikely to significantly influence the seedling emergence. Such changes in cropspecies producing different purpose may be more critical. This research also indicated that there was little difference in the seedling emergence rate but this seedling emergence rates did not significantly effect by photoperiod. However, photoperiod significantly effected on emergence in some plants (Anonymous, 2004; Benvenuti *et al*., 2001).

In summary, this study demonstrates flax varieties can be selected for early seedling emergence at low temperatures. Windemore, intermediate in seed size, had the highest rates at cool temperatures while Sarı-85 was the lowest. Temperature had a dramatic effect on the seedling emergence rate, particularly at the cooler temperatures. The seed emergence responses of flax to various treatments in this study also indicate that this plant is well adapted to environmental condition in high temperature areas than low temperature areas.

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