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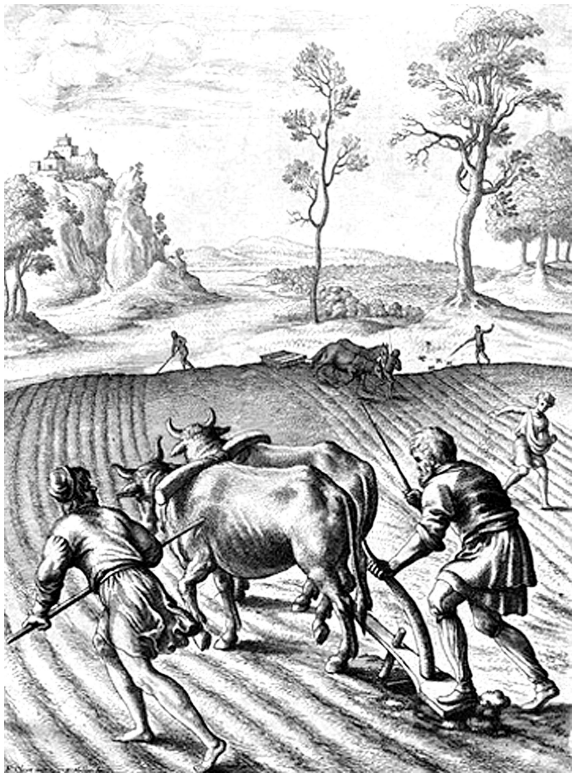

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Study of Cardinal Temperatures for Pumpkin (*Cucurbita pepo*) Seed Germination

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Abstract: The effect of a range of constant temperatures (10-35°C) on the germination of *Cucurbita pepo var. styriaca* seed was investigated to quantify the relationship between temperature and the rate of seed germination and to study the effect of conditioning temperature on the relationship. Seeds were conditioned on moist filter paper either at 25 or 20°C for 14 days in an incubator. No seeds of C. *pepo* conditioned at 25°C, germinated at <12.5°C or >35°C within 312 h. For seeds conditioned at 20°C, germination occurred at temperatures between 15 and 35°C within 312 h. The base (Tb, estimated from extrapolation), optimum (To) and ceiling (Tc) temperatures determined were: Tb = 17.6°C, To = 28°C and Tc>35°C for seeds conditioned at 20°C compared with Tb = 13.7°C, To = 25-27.5°C and Tc>35°C for seeds conditioned at 25°C. Positive linear relationships were established between the rates (reciprocal of time taken) of germination of 90% of the final germination percentage and temperature up to the respective optimal temperatures. The rate of germination for seed conditioned at 20°C was lower than for seed conditioned at 25°C. Similarly base and optimum temperatures were lower for seed conditioned at 25°C.

Key words: *Cucurbita pepo*, seed germination rate, cardinal temperatures, conditioning

INTRODUCTION

Pumpkin *(Cucurbita pepo)* is an annual medicinal plant which belongs to the *Cucurbitaceae* family. The seeds and oils extracted from pumpkin seeds contains vitamin E and beta sitosterol and used in medicinal industries (Chevallier, 1996).

Plant growth is very sensitive to temperature. Each species has, at any given stage in its life cycle and in any given set of conditions, a base temperature below which it will not grow, an optimum temperature (or range of temperatures) at which it grows or may even die (Salisbury and Ross, 1992).

A number of studies have been made of the response of pre-emergence seedling growth to temperature (Wheeler and Ellis, 1991; Weaich *et al*., 1996). Different methods have been used to describe growth data from different species, but in many cases a thermal time approach has been adopted which assumes growth rate is linearly related to temperature. This approach can provide useful predictions of the timing of seedling emergence for some applications. However, linearity usually occurs over a limited temperature range. The approach assumes that there is a linear relationship between developmental rate (1/td, d^{-1}, where td is the duration of a given developmental phase) and temperature (T, °C) between the base and optimum temperatures (Ellis and Barrett, 1994).

Pumpkins are warm season crops and at North-west of Iran germination of the seeds at lower temperatures will provide sufficient growing season and the higher crop yield. Temperatures between 21 and 35°C have been regarded as optimal for germination of pumpkins (Molinar *et al*., 2004), but the cardinal temperatures for *Cucurbita pepo* seed germination have not been determined using mathematical method hitherto. Conditioning is the period that seeds exposed to moisture at a certain temperature before germination, which can affects the base and optimum temperatures for seed germination. The objectives of this study were: To quantify the relationship between temperature and rate of germination for a seed lot of *Cucurbita pepo*; to estimate values of the cardinal temperatures (base, optimum and ceiling) and to study the effect of two conditioning temperatures on the relationship between germination rate *Cucurbita pepo* and temperature.

MATERIALS AND METHODS

This study was conducted during 2003 year at Ecology and Medicinal Plants Laboratory of Agricultural Faculty, University of Tabriz, Iran. In the two investigations, *Cucurbita pepo* var. *styriaca* seeds were incubated on moist filter paper either at 25°C or at 20°C for 14 days to condition the seeds. Approximately 25 seeds were placed on each glass. The discs were immediately placed on the temperature gradient plate at constant temperatures ranging from 10 to 35°C at 2.5°C intervals. A total of four replicates were used in CRD design. A seed was considered as germinated if the

radicle was visible about 2 mm. Germination was observed at 2 h intervals for the first 24 h and at 10-12 h intervals thereafter for a total of 312 h.

At each temperature the data from the four replicates were bulked and used to plot mean cumulative germination curves against time. From these curves estimates of the time to 90% of the total germination achieved were obtained by interpolation [i.e., if the total germination was 80% of the seed present, then time to 90% germination would be when 72% of all the seed present had germinated; Dumur *et al*., 1990]. The reciprocals of the time to germination at each were plotted against temperature to estimate the optimum temperature at which the rate of germination was maximal, To. The rates of germination were then subjected to regression analysis using the equations introduced by Garcia-Huidobro *et al.* (1982). The equation used to describe the rates of germination below and up to an optimum temperature was:

$$1/t = [T-Tb]/\theta 1 \quad (1)$$

Where, t = time taken in days for cumulative germination to reach a given percentage; T = temperature (°C); Tb = base temperature for the given sub-set of the seed-at which temperature 1/t is zero (intercept on the temperature axis); θ1 = thermal time (number of degree-days above Tb required by the seed to germinate). To describe responses above to but below the ceiling temperature, Tc, Eq. 2 was used:

$$1/t=[Tc-T]/\theta 2 \quad (2)$$

At Tc, 1/t is again zero and θ2 is the second value of thermal time.

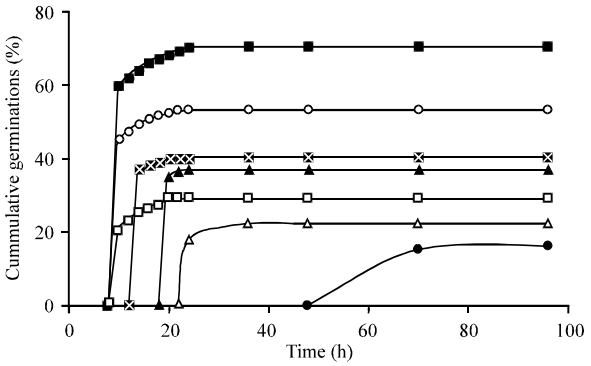

Fig. 1: Representative curves of cumulative germination of *C. pepo* seed at different temperatures following conditioning at 25°C for 14 days at 15°C (●); 17.5 (Δ); 20 (□); 22.5 (×); 25 (o); 32.5 (■) and 35°C (▲). Cumulative germination did not change appreciably with time after 70 h

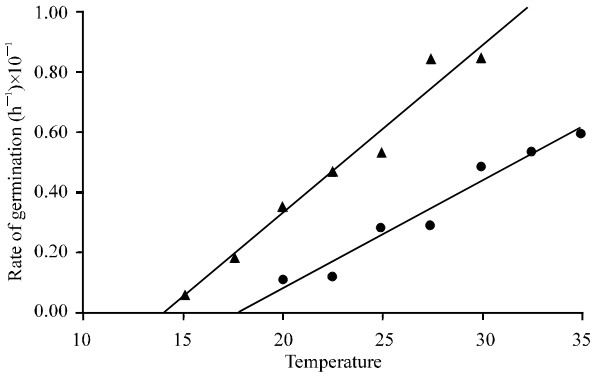

Fig. 2: Relationship between temperature and the rate of germination of *C. pepo* seed conditioned at 20°C for 14 days (●) or 25°C for 14 days (▲) at sub-optimal temperatures

RESULTS

There was a significant difference in germination percentage between temperature treatments ($p<0.005$). Figure 1 shows representative mean cumulative germination curves for *C. pepo* seed conditioned at 25°C at different temperatures. The curves for seed conditioned at 20°C were similar in shape and are therefore not presented.

No seeds of *C. pepo* (conditioned at 25°C for 14 days) germinated below 12.5°C or above 35°C within 312 h. Seeds conditioned at 20°C for 14 days germinated between 15 and 35°C. Onset of germination was about 10 h for the temperature range of 25-35°C, 12-16 h for 20-22.5°C, 22 h for 17.5°C and 72-96 h for 10-12.5°C for seeds conditioned at 25°C (Fig. 1). For seeds conditioned at 20°C, germination began at about 10 h for the temperature range of 22.5-35°C and 48 h for 17.5-20°C. Germination at all temperatures for both conditioning temperatures occurred in a flush, reached a maximum percentage with no further increase within the rest of the period of the study. There was also a significant temperature by conditioning interaction effect on the rate of germination ($p<0.005$, Fig. 2).

The cardinal temperatures (base, optimum and ceiling) were determined by linear regression analyses of the rates of germination (up to the respective optimal temperatures) against temperature. The intercepts of the fitted regression lines on the temperature axes estimated the base temperatures (Tb) as about 17.5°C for seeds conditioned at 20 and 13.7°C for seeds conditioned at 25°C (Fig. 2). The ceiling temperature was >35°C based on

the germination response of conditioned seeds to temperature. The base and optimum temperatures for seed conditioned at 20°C were higher than for seed conditioned at 25°C.

DISCUSSION

These experiments showed that the linear regression method can be used for determination of the cardinal temperatures for pumpkin seed germination. Conditioning of the seeds affected thermal requirement of *C. pepo* seeds for germination as expected. For seeds conditioned at 25 and 20°C, there was a positive linear relationship between temperature and germination rate of *C. pepo* from 20°C to about 35-37.5 and 27.5-42.5°C, respectively. Germination was generally low in this study probably because three year old seed was used.

Molinar *et al.* (2004) reported that the optimal germinating temperature range for pumpkin is 70 to 95°F (21 to 35°C), the maximum germinating temperature is 100°F (38°C) and below 60°F (15.5°C) germination may take as long as 2 weeks. Previous works on *C. pepo* germination has tended to ignore the effect of temperature on the rate of germination. Seeds were frequently conditioned in water at temperatures above 20°C for 2-3 weeks and germinated at temperatures between 25-35°C. Germination was then observed after 24 h (Hsiao *et al.*, 1988). This study showed that in the temperature range 20-35°C germination (visible emergence of radicle) of *C. pepo* began at about 10 h. The onset of germination was progressively delayed below these temperatures. The base and optimum temperatures were about 3-8 and 5-8°C higher for seeds conditioned at 20°C than for seeds conditioned at 25°C. This shows that to germinate seeds conditioned at lower temperatures higher temperatures are needed. It has been suggested that conditioning of *C. pepo* seed results either in the leaching of chemical germination inhibitors from the seed; or promotes the synthesis of a germination stimulant in the seed or increases the permeability of a component within the seed such as the aleurone layer (Okonkwo, 1991). Probably the higher conditioning temperature used in this study enhanced the physiological mechanisms enumerated above more effectively hence the higher rates of germination and germination at lower temperatures. Ceiling temperatures, Tc, could not be accurately established due to insufficient data points in the supra-optimal temperature range; but was >35°C. Previous works did not estimate cardinal temperatures for germinating *C. pepo*.

The base temperature for *C. pepo* seed germination was higher than the seeds experience during field germination at North-West of Iran. Lower soil and cool air temperature in the spring often limits the germination of pumpkin seeds, greatly reducing seedlings vigour and crops ability to compete with weeds. In conclusion, conditioning of the seeds especially at 25°C is suitable for faster germination of pumpkin seeds at field conditions.

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