Temperature Effects on Sugarbeet Seedling Emergence

L. G. Campbell[1] and J. W. Enz[2]

[1]*USDA-ARS, Northern Crop Science Laboratory, Fargo, ND 58105-5677, and*

[2]*Soil Science Department, North Dakota State Univ., Fargo, ND 58105*

ABSTRACT

Sugarbeet (*Beta vulgaris*) producers in northern production areas attempt to take full advantage of the short growing season by planting as early as field conditions allow while adjusting the planting date based upon their perceived risk of stand loss from low temperature. Stand loss can occur from frost injury after emergence, but soil temperature influences the rate of seedling emergence and may influence final stand. This study determined the effects of temperature on seedling emergence of 14 sugarbeet hybrids. All experiments were conducted in the laboratory on a thermogradient plate at temperatures between 10 and 25°C. Nonsignificant hybrid effects and significant hybrid × year interactions suggested that differences in seed lots (seed produced in different years) were of greater magnitude than differences among hybrids for percent emergence and emergence rate. Percent emergence 14 d after planting reached a maximum and appeared to level off at 22°C. The rate of emergence, measured by the coefficient of velocity, increased linearly over the range of temperatures studied. Peak emergence percent was not influenced by temperature. At 25°C, peak emergence occurred 7 d after planting in 1985 and 9 d after planting in 1986. Corresponding times for 17°C were 12 and 13 d in 1985 and 1986, respectively. The heat units required for 50% emergence appeared to be independent

of temperature. Heat units required for 50% emergence and soil temperature data were combined to illustrate the effect of planting date on seedling emergence time in the field. Similar calculations for any location where daily soil temperature information is available would provide objective information for determining planting date.

Additional Key Words: *Beta vulgaris* L., Germination, Stand establishment, Thermogradient plate.

Sugar producers in northern production areas prefer to take advantage of the nonlimiting growth cycle of sugarbeet (*Beta vulgaris* L.) by planting as early and harvesting as late as weather permits. Rapid stand establishment facilitates early season weed control and, in some years, may be a factor in avoiding soil crusting and reducing seedling diseases and insect damage. The need to balance lengthening the growing season with obtaining adequate stand establishment requires an understanding of the factors influencing stand establishment.

Temperature is a major factor influencing seed germination and seedling emergence and hence stand establishment. Low temperature may prevent or delay emergence and freezing temperatures can kill emerged plants. Soil temperature often may be more important for determining optimum planting date than soil moisture (Wanjura and Buxton, 1972). Soil temperatures change gradually and can be measured easily or obtained from weather reports; as compared to the rapid changes in soil moisture resulting from spring rains which are frequently sporadic in amount and intensity. Cultivar, seed lot, and cultural practices also influence seedling emergence and stand establishment (Akeson and Widner, 1980; Durrant et al., 1988).

Because of the economic importance of uniform stands (Winter, 1980), factors influencing seedling emergence and measurements of seed quality have been and continue to be the focus of research projects. Durrant et al. (1985) found that small differences in standard laboratory germination percent resulted in large differences in field establishment success. Establishment rates for various seed lots and locations ranged from 19 to 94% of the seed planted. Further study (Durrant, 1988) showed a positive relationship between rapid emergence and a high emergence percent. Fornstrom and Pochop (1974) concluded that soil temperature during the emergence period was a stand limiting factor and that accumulated heat units provided a useful index of emergence success. Soil temperatures were probably responsible for the positive association between planting date and final stand observed by Yonts et al. (1983). Gummerson

(1986) used temperature and moisture (osmotic potential) to derive an equation describing the germination process.

Wood (1952) was successful in selecting for low temperature germination and Smith (1952) observed "striking" varietal differences in seedling vigor at low temperatures but only minor differences at optimum germination temperatures. Snyder (1963) was unsuccessful in selecting for rapid germination and concluded that differential speed of germination was regulated by the maternal tissues of the seedball. While many breeders select for seedling vigor in their hybrid development programs, no concerted effort to develop rapidly emerging genotypes has been reported.

The importance and difficulty of obtaining adequate stand establishment has stimulated the development of laboratory tests to predict field establishment. Although most commercial companies sell seed with high germination, seed lots differ in their establishment ability. Akeson and Widner (1988) found that emergence through packed sand predicted field emergence of sugarbeet. Indices have been developed to characterize speed of germination or emergence (Maguire, 1962; Czabator, 1962). Larsen (1971) described the construction of a thermogradient plate. This device provided an effective method of controlling temperature and has been employed by a number of workers to study the impact of temperature on germination and emergence (Cole, 1972; Webb et al., 1978; Lawlor et al., 1990). Review articles by McDonald (1975) and Scott et al. (1984) discuss the utility and limitations of many of the widely accepted measures of germination and seedling emergence success.

This paper examines differences in seedling emergence among 14 commercial sugarbeet hybrids at temperatures between 10 and 25°C. The effects of temperature on percent emergence and speed of emergence were measured on a thermogradient plate. These measurements are compared to seasonal soil temperatures with the intent of suggesting optimum planting dates for rapid full stand establishment.

MATERIALS AND METHODS

Seed of commercial sugarbeet hybrids were planted on a one-way thermogradient plate (Larsen, 1971). The plate was divided into 23 rows with polyethylene strips which confined the roots to a channel 15 mm wide at each temperature. Twenty-five seed of each hybrid were planted in the channels and covered with 20 mm of sterile silica sand. Temperatures ranged from 10 to 25°C. Emergence counts were made daily for 14 days. The experiment was replicated four times in 1985 and 1986. Hybrids included in both the 1985 and 1986 commercial yield trials were observed. The following hybrids were examined: 'ACH 164', 'ACH 176', 'Beta 1230', 'Beta 6264', 'BJ 19', 'Hilleshog 4046', 'KW 1132', 'KW 3265', 'KW 3394', 'Maribo 403', 'Monoricca', 'Puressa II', 'GW R-103', and 'Ultramono'. Seed was obtained from commercial sources and a new seed lot was obtained for each year's test. Experiments were conducted in the spring of each year. Seed age and quality duplicated that encountered in commercial production. Percent emergence 14 d after planting and three indices of emergence speed were calculated. The analysis of variance for percent emergence was performed on arcsine transformed data. Very few seedlings emerged at temperatures below 11°C; hence, only temperatures above 11°C were included in the analysis of variance.

Days to 50% emergence, coefficient of velocity, and peak emergence time were used as indicators of emergence speed. Days to 50% emergence was the days after planting at which emergence reached at least 50% of the average final emergence at 25°C for each hybrid and year combination. The coefficient of velocity (CV) was calculated as:

$$CV = 100\ (\Sigma\ N_i\ /\ \Sigma\ N_iT_i)$$

where N_i is the number of newly emerged seedlings on day i and T_i is the number of days after planting (Scott et al., 1984). CV increases as more seedlings emerge in a shorter time. Peak emergence time was the point at which the cumulative emergence percent divided by the days after planting was at its maximum (Czabator, 1962). A peak time and corresponding cumulative emergence percent were identified for all temperatures each year.

Heat units (HU_{50}) required for 50% emergence were calculated as follows:

$$HU_{50} = (T - T_{min})\ D$$

where T was the temperature of observation, T_{min} was 4.4°C and D was the days to 50% emergence. Heat units and soil temperatures were used to predict field emergence times. Soil temperature was the daily average temperature 5 cm below a bare soil surface at Fargo, North Dakota. Climatological data were collected and are maintained by the Soil Science Department, North Dakota State University.

RESULTS AND DISCUSSION

Year, year × temperature, year × hybrid, and temperature × hybrid effects were significant (P = 0.05) for percent emergence after 14 days. Hybrid and hybrid × year × temperature effects were non-significant. Average emergence at 25°C was 69% compared to 8% at 11°C. The inability to randomize temperatures on a thermogradient plate prevented the testing of temperature effects; however, the magnitude of the differences and the response pattern left little doubt about the influence of temperature on emergence.

Average emergence was 59% in 1985 and 46% in 1986. Whether this difference was caused by environmental conditions in the laboratory or seed quality could not be determined. While every attempt was made to standardize laboratory conditions, small differences in moisture content of the sand, room temperature, or some other factor may have deterred emergence in 1986. Almost all commercial seed grown in the U.S. is produced in the Willamette Valley of Oregon, so it is conceivable that seed produced for the 1986 crop may have been, in general, inferior to that sold for 1985 production. Lawlor, et al.(1990) documented that seed production environment can influenced germination of sorghum (*Sorghum bicolor* (L.) Moench). The range of replication means (replication was over time) for 1986 was similar to that observed for 1985. This and the observation that some hybrids performed equally well in both years suggested that differences in seed quality (seed lots) caused the observed differences in emergence percent.

The nonsignificant hybrid effect suggested that no single hybrid or group of hybrids exhibited superior emergence. The significant hybrid × year interaction suggested that differences between seed lots may be more important than differences between hybrids. This conclusion would be consistent with the large differences in seedling vigor among seed lots observed by Akeson and Widner (1980). Differences between 1985 and 1986 emergence percents were not significant for four of the 14 hybrids examined. Average hybrid emergence for 1985 ranged from 2% lower to 33% higher than 1986 emergence. An examination of hybrid × temperature means did not identify a hybrid or group of hybrids that were uniquely adapted to extreme temperature conditions. Differences among hybrids appeared to be greater at higher temperatures than at lower temperatures.

At lower temperatures percent emergence was similar in both years (Fig. 1). The differences between years increased as temperature increased. The significant temperature × year interaction probably resulted from this pattern. At 25°C average emergence was 77% in 1985, compared to 61% in 1986. The regression of emergence percent on temperature indicated that emergence percent reached a maximum approximately 22°C (22.1° in 1985 and 22.9° in 1986). Percent emergence did not increase beyond that temperature. If emergence would have been allowed to continue for longer than 14 days, the temperature at which maximum emergence was reached would be expected to decrease and larger differences in emergence percent may have occurred at lower temperatures.

Speed of emergence, as measured by the coefficient of velocity, behaved similar to percent emergence. Year, year × temperature, and year × hybrid effects were statistically significant. The temperature × hybrid effect for CV was not significant, as had been the case with percent emergence. Hybrid and hybrid × year × temperature effects were nonsignificant. The nonsignificant hybrid effect and the significant year × hybrid interaction again implied that different seed lots of a hybrid may perform differently. Average CV's were 10.3 in 1985 and 9.3 in 1986. Some of the difference between the two years

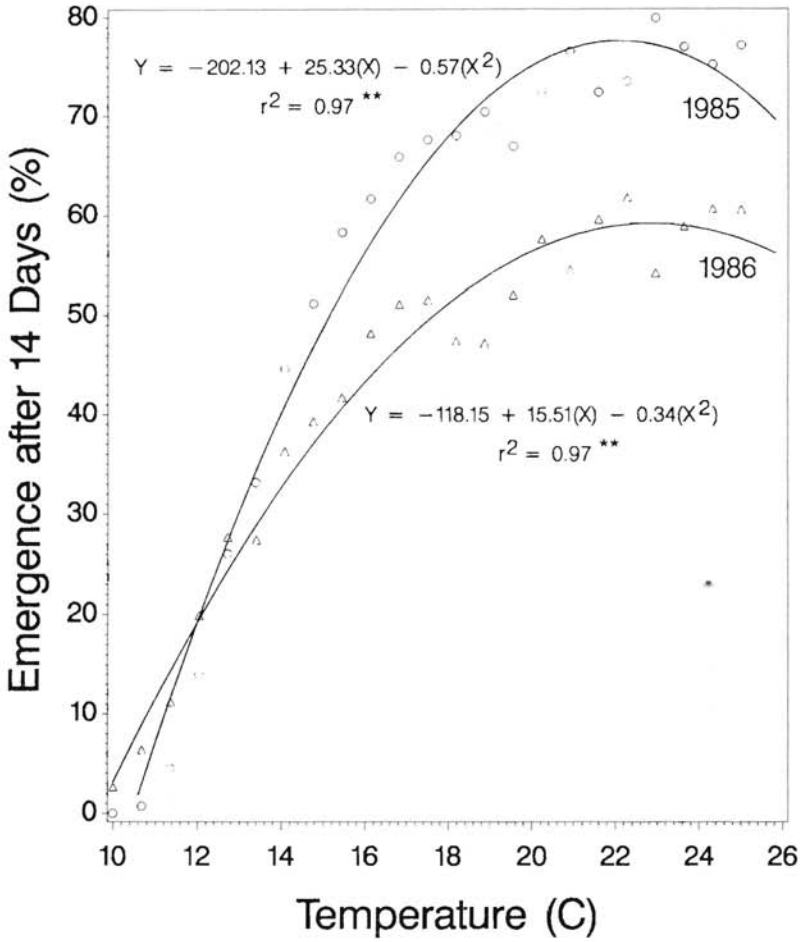

Figure 1. Average seedling emergence percent of 14 sugarbeet hybrids at various temperatures on a thermogradient plate in 1985 and 1986.

is a refelection of the difference in average emergence percent (Scott et al., 1984). Hybrid average CV's for 1985 ranged from 1.0 lower to 4.2 higher than 1986 CV's. Spearman's rank correlation was used to compare year × hybrid differences in CV to year × hybrid differences in emergence percent. The results suggested differences in percent emergence after 14 days were not closely related to differences in speed of emergence (r_s = 0.56). The relationship between CV and temperature appeared to be linear (Fig. 2).

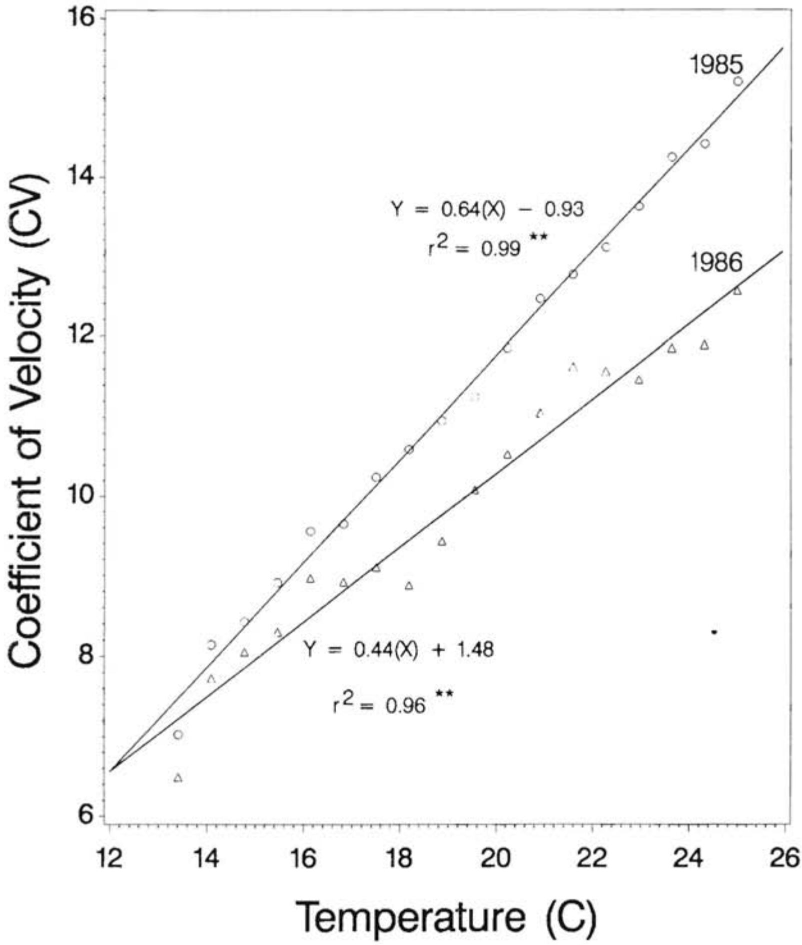

Figure 2. Average emergence speed (coefficient of velocity) of 14 sugarbeet hybrids at various temperatures on a thermogradient plate in 1985 and 1986.

Emergence was slower in 1986 than in 1985 with the defference between the years increasing as temperature increased.

The above relationships also were apparent in the cumulative distributions for percent emergence (Fig. 3). Peak emergence (the

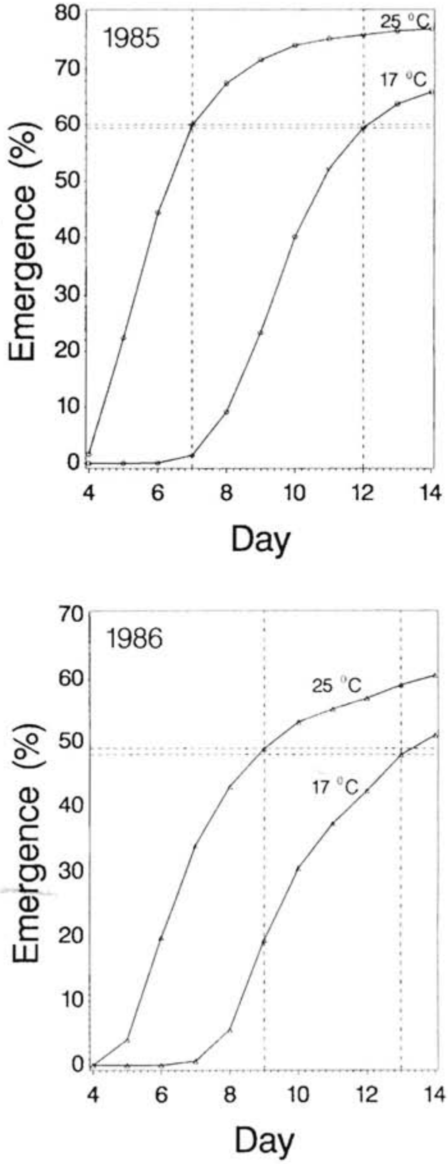

Figure 3. Cumulative emergence percent of 14 sugarbeet hybrids at 17 and 25°C, 1985 and 1986 (dashed lines indicate peak emergence times and percents).

point where emergence percent/days was at its maximum) at 25°C occurred at 7 days in 1985 and 9 days in 1986 with peak emergence percents of 60% and 49%, respectively. Lowering the temperature to 17°C increased peak emergence time by 5 days in 1985 and 4 days in 1986. Peak emergence percent was not influenced by temperature. A similar relationship between emergence rate and final emergence percent was reported by Yonts et al., (1983). Average peak emergence was 62% (SD = 2) in 1985 and 48% (SD = 3) in 1986. The lowest temperature with a peak emergence time of less than 14 days for both years was 17°C.

Days to 50% emergence provided another measure of emergence speed. As before, seedlings emerged quicker in 1985 with the difference between years increasing as the temperature increased (Fig. 4). Days to 50% emergence appeared to reach a minimum at approximately 25°C (26.2 in 1985; 24.7 in 1986) in both years; however, more than an additional day was required for 50% emergence to reach the minimum in 1986. More than 14 days were required for 50% emergence at temperatures below 14°C. Approximately 136 (SD = 10) heat units were required for 50% emergence at all temperatures. The utility of heat units for predicting sugarbeet emergence has been documented by Fornstrom and Pochop (1974) and Yonts et al. (1983).

Heat units were employed to predict field emergences time at Fargo, North Dakota (Fig. 5). Between 15 April and 31 May average soil temperatures (1981-1989) increased linearly from 6.2 to 18.6°C at a rate of 0.27°C d^{-1} ($r^2 = 0.95$). For seed planted on 15 April, 23 d were required for 50% emergence, compared to 9 d for a 18 May planting. The earliest average planting date for obtaining a 50% stand in 14 d or less was 28 April; in 10 d or less, 13 May. The probability of a killing frost (-2.2°C) after these dates is 0.7 for 28 April and 0.2 for 13 May. Soil warming rates were not constant from year to year. For example, for a 15 April planting in 1987 one would have expected a 50% stand by 27 April, a 15 May planting would have emerged on 26 May. This pattern is in contrast to 1982 when a 15 April planting would not have reach 50% emergence until 8 May. This was only 17 d earlier than the 25 May emergence date expected for a 15 May planting. This contrast suggests a feasible explanation for inconsistency in the benefit of early planting. Predicted emergence times should be considered minimum times. If a seedbed is dry at planting, the day that adequate rainfall occurs may become the effective planting date. Yonts et al. (1983) observed that the heat units required for 50% germination increased as moisture stress increased. Planting depth and seedbed conditions also influence emergence time; however, relative times would remain similar to those reported here.

The relationships between temperature and emergence observed on the thermogradient plate should be applicable to all sugarbeet production areas. Observations were limited to 14 d on the assumption that conditions requiring longer emergence times would not be acceptable in commercial production. One location provided an illustration of how the observed relationships can provide information for management decisions or to explain a portion of the variability among environments. The relationships discussed could be adapted easily to any location for which soil temperature data are available.

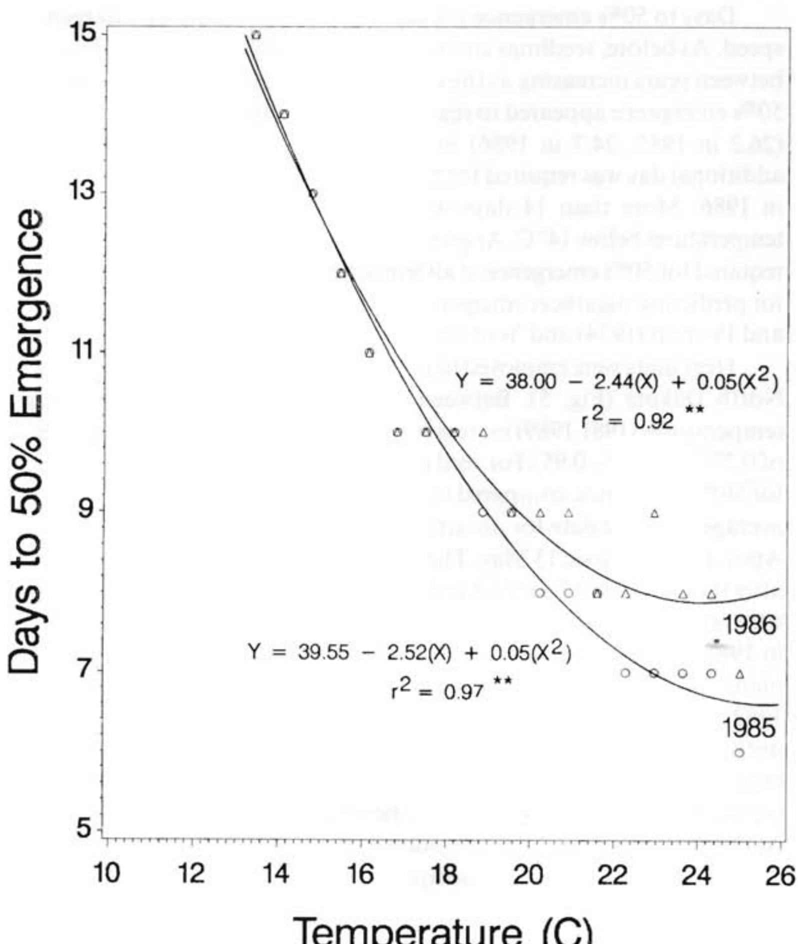

Figure 4. Days to 50% emergence (based upon final emergence of each hybrid × year combination at 25°C) for 14 sugarbeet hybrids at various temperatures on a thermogradient plate in 1985 and 1986.

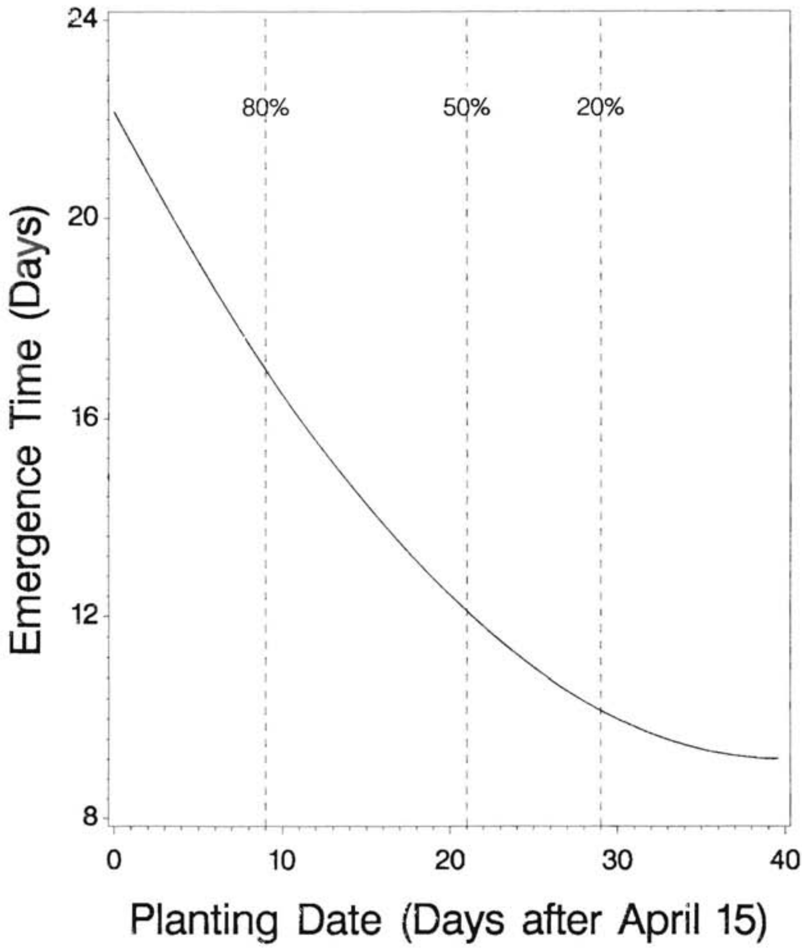

Figure 5. Estimated average field emergence time for sugarbeet planted between 15 April and 31 May at Fargo, North Dakota, 1981-1989 (dashed columns indicate the probability of air temperatures below -2.2°C on or later than the date indicated).

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