# Influence of sowing date and hybrid on maize emergence

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## Abstract

Four maize hybrids, CTL102, CTL90, N21V6 and N59Q9 were sown in spring 2006 on 6 and 27 October and 21 November. Plots were a single row with 50 seed sown at a depth of 5 cm with 10 cm spacing. Establishment was measured by monitoring plots for seedling emergence and subsequently taking daily counts of the number of emerged seedlings in each plot until emergence counts stabilised. Emergence data was subject to ANOVA and non-linear regression analysis using the Gompertz model. Soil temperature (5 cm) was used to calculate the thermal time required between sowing and 50 % emergence. A base temperature of 6 $^{o}$C was found to be most appropriate. There were significant hybrid differences in final emergence, time to 50 % emergence and 28 d seedling dry weight. Hybrid CTL102 emerged significantly more slowly at all sowings and had a greater thermal time requirement to 50 % emergence than the other three hybrids. Later sowing decreased the time to 50 % emergence, a consequence of higher soil temperatures. However, the thermal time requirement to 50 % emergence was relatively stable across sowings. The Gompertz model gave a good description of the time course of seedling emergence.

***Additional Key words:*** *Zea mays*, hybrid, sowing date, seedling emergence, soil temperature, thermal time

## Introduction

Achieving high maize (*Zea mays* L.) grain yields requires that full season hybrids are sown early to fully exploit the thermal time available over the growing season (Wilson *et al.*, 1994). However, early sowing can be conflicted by low spring soil temperatures, which can reduce seed germination, the rate of seedling emergence and final establishment (Hayhoe *et al.*, 1996). Delayed, and poor emergence, can significantly reduce yield and in extreme cases result in paddocks having to be resown. Further, soil temperature controls the rate of development in maize crops until the six leaf stage because the plant meristem is below ground level until this stage (Stone *et al.*, 1999). Current recommendations in New Zealand are that maize should only be sown when soil temperature is consistently > 10 $^{o}$C. (White *et al.*, 1999).

Cool temperature tolerance, particularly early in the season, has been a goal in maize breeding programs in New Zealand (Eagles and Brooking, 1981) and overseas (Frei, 2000) to produce hybrids with more reliable yields. The maize hybrids currently grown in New Zealand mostly originate from North American and European breeding programs but are rated for their early growth under New Zealand field conditions. These hybrid ratings are made available to maize growers to aid hybrid selection (Anon 2006a; Anon 2006b). The objectives for this study were to determine the effect of sowing date on the emergence, early growth and thermal time requirements of four maize hybrids with different early growth scores.

## Materials and Methods

Four maize hybrids (Table 1) from Corson Grain Ltd, Gisborne, were hand sown into a cultivated seedbed on the Pasture and Crop Research Unit, Massey University. Hybrids CTL90 and CTL102 are both leafy and are characterised by a high leaf number and high leaf area above the ear (Modarres *et al.*, 1997). The soil type was a Manawatu fine sandy loam, which had previously been sown in a Brassica forage crop. Seed of each hybrid was hand sown in 5 m rows, 50 seeds row$^{-1}$ at 5 cm depth on 6 and 27 October and 21 November 2006 in a factorial design with three replicates. Soil was cultivated with a hand hoe prior to each sowing so that seedbed conditions were similar for each sowing. No fertiliser or herbicide was applied.

**Table 1.** Description of maize hybrids used.

| Characteristic | CTL90 | CTL102 | N21V6 | N59-Q9 |
|---|---|---|---|---|
| Silage relative maturity | 90 | 104 | 85 | 107 |
| Early growth score* | 2 | 5 | 4 | 3 |
| Seed weight (mg) | 265 | 246 | 254 | 331 |
| Seed germination (%) | 93 | 90 | 98 | 88 |
| Cold test germination (%)+ | 64 | 85 | 93 | 80 |

*1 to 9, 1 = best: +% vigorous seedlings after exposure to 10 °C for 7 d.

A standard germination test and cold test was conducted on each seed lot prior to sowing by Seed Technology Services, Massey University. Seed weight was determined by counting and weighing 150 (50 seeds x three replicates) seeds from each seed lot. All seed was treated with the fungicide Vitaflo 200® (carboxin 200 g l$^{-1}$ and thiram 200 g l$^{-1}$).

After each sowing the site was monitored for seedling emergence. Maize seedlings were counted as emerged when the coleoptile was > 1.0 cm above the soil surface. After emergence began daily emergence counts were taken, on each plot until emergence was complete. At 28 d after each sowing 10 seedlings plot$^{-1}$ were sampled to estimate seedling dry weight. Seedlings were dug by hand and the coleoptile cut just above the nodal roots; the roots, mesocotyl and remaining seed were discarded. Seedlings were dried at 85 °C and weighed.

Temperature and rainfall records from the meteorological station at AgResearch, Palmerston North, approximately 300 m from the trial site, were used to assess the impact of climate on the seedling emergence characteristics of each hybrid. Soil temperature at 5 cm depth was used to estimate the thermal time requirement to 50 % emergence. This was estimated from the mean of the 10 cm and soil surface temperatures (Chris Hunt, AgResearch, Palmerston North Pers. Comm.), measured hourly. The base temperature used in thermal time calculations was 6.0 °C (Bonhomme *et al.*, 1994) after comparison of the coefficient of variation (CV) of thermal time across sowing dates for a range of base temperatures. Mean CV's declined significantly ($p < 0.05$) from 11.4 to 7.0 to 4.6 % at base temperatures of 8.0, 7.0 and 6.0 °C respectively. However, in CTL102 the minimum CV was at a base temperature of 5 °C.

Data was analysed using SAS. Analysis of variance was undertaken using PROC GLM. PROC NLIN was used to generate the regression coefficients for a Gompertz function describing seedling emergence of each hybrid at each sowing date. These coefficients describe the shape of the Gompertz curve and coefficients from different functions (hybrid and sowing date) can be tested to give an indication of significant differences between functions. The emergence rate used for the Gompertz function was determined as the ratio of emerged seedlings at each sampling and the final emerged seedling number. The Gompertz function (Equation 1) was utilised because it has been shown to adequately represent seedling emergence data (Cheng and Gordon, 1999).

$$Y = \boldsymbol{a} \exp(-\exp(-\boldsymbol{b}(x-\boldsymbol{c}))) \qquad \text{Equation 1}$$

where Y = % of final emergence on day x, ***a*** = upper asymptote, ***b*** describes the slope at the flex and ***c*** is 50 % of ***a***.

## Results

### Climate

Spring 2006 in the Manawatu was cold, windy and wet with occasional heavy rainfall events. Consequently many maize crops initially failed to establish and had to be resown (Mark Richards, Genetic Technologies Ltd, Personal Communication). Mean air and soil temperatures recorded at AgResearch were 0.8 $^{o}$C lower than the long term mean (LTM) in both October and November (Table 2). The 10 cm soil temperatures were 0.9 and 1.4 $^{o}$C lower than the LTM during these months whereas rainfall was well above the LTM in both months, October received almost twice normal rainfall. Windrun was also well above (39 and 49 % for October and November respectively) the LTM in both months.

**Table 2.** Mean daily air ($^{o}$C) and soil temperatures (10 cm @ 9.00am), daily wind run (km) and monthly rainfall (mm) during spring 2006 compared with the long term mean (LTM) at AgResearch, Palmerston North.

| | Rainfall | | Air Temp | | Soil temp. | | Wind | |
|---|---|---|---|---|---|---|---|---|
| | 2006 | LTM | 2006 | LTM | 2006 | LTM | 2006 | LTM |
| October | 172 | 88 | 11.6 | 12.4 | 11.6 | 12.5 | 376 | 270 |
| November | 133 | 78 | 13.4 | 14.2 | 13.7 | 15.1 | 421 | 286 |

### Seedling emergence and seedling dry weight

Seedling numbers were generally good in all cultivars. However, there were significant ($P < 0.0001$) hybrid differences with 41.4, 43.6, 45.3 and 46.9 emerged seedlings for CTL90, CTL102, N59-Q9 and N21V6 respectively. The rate of seedling emergence after correcting for laboratory seed germination (% of seeds producing a normal seedling) also differed among hybrids ($p < 0.0001$). Emergence was lowest in CTL90 (89.1 %) and highest in NQ-59 (103.0 %) indicating that most of the seedlings categorised as abnormal during the germination testing of this hybrid (5 %) actually emerged. There were no differences among sowing dates for seedling numbers or emergence (Table 3).

Hybrids CTL90 and CTL102 produced significantly ($p = 0.0001$) lighter seedlings at 28 d after sowing than N59-Q9 and N21V6. There was also a small but significant ($p = 0.03$) sowing date effect on seedling weight, seedlings from the second sowing (2.35) weighed more than those from the third (2.08).

### Time course of emergence

The Gompertz regressions (Figure 1, Table 4) gave a good fit for the emergence data for all hybrids and sowing dates. Coefficients of determination were very high, at > 0.99 in all regressions. They show hybrid differences in time to 50 % emergence (*c* coefficient, Table 4). Seedlings of N59-Q9 and N21V6 generally had a similar emergence pattern and emerged earlier than CTL90 and CTL102 seedlings. Seedlings of CTL90 emerged earlier than CTL102 seedlings. Time to 50 % emergence was reduced ($p = 0.05$) by later sowing in all hybrids apart from CTL102 in which the time to 50 % emergence was similar at the second and third sowings. This gave a decrease in time to 50 % emergence between the first and last sowing of 3.3, 3.8, 3.9 and 4.2 days for CTL102, CTL90, N21V6 and N59-Q9 respectively.

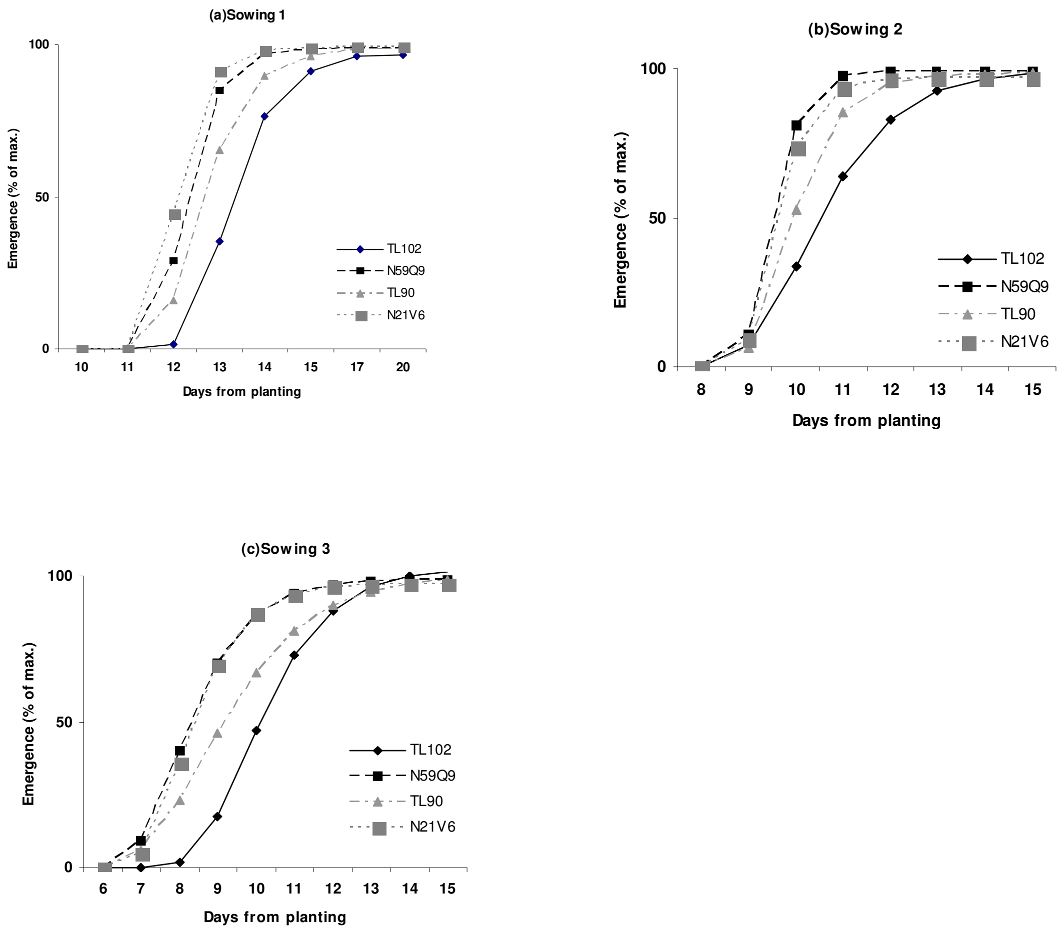


**Figure 1**. Gompertz regressions for each maize hybrid and sowing date.

The *b* coefficients for N59-Q9 and N21V6 were significantly higher than for CTL90 and CTL102 at all sowing dates (Table 4) indicating a slower seedling emergence rate in the leafy hybrids. Seedling emergence rate was significantly lower at the third sowing compared with the first two sowings in hybrids CTL90, N21V6 and N59-Q9 whereas for CTL102 there was a significant decrease between the first and second sowing.

There were significant hybrid differences in thermal time among sowings and 50 % seedling emergence (Figure 2) which were consistent for all sowing, reflecting calendar time to 50 % emergence. Hybrid CTL102 required more thermal time than all other hybrids, apart from CTL90 at the second sowing. However, there were no significant differences between the remaining hybrids.

## Discussion

The Gompertz regressions gave a good description of the seedling emergence profiles (Figure 1). Gompertz models have been found to be suitable for time course studies of germination and emergence in a number of crops (Cheng and Gordon, 2000; Vamerali *et al.*, 2006). The regression coefficients generated (Table 4) allowed an objective comparison of different aspects of seedling emergence.

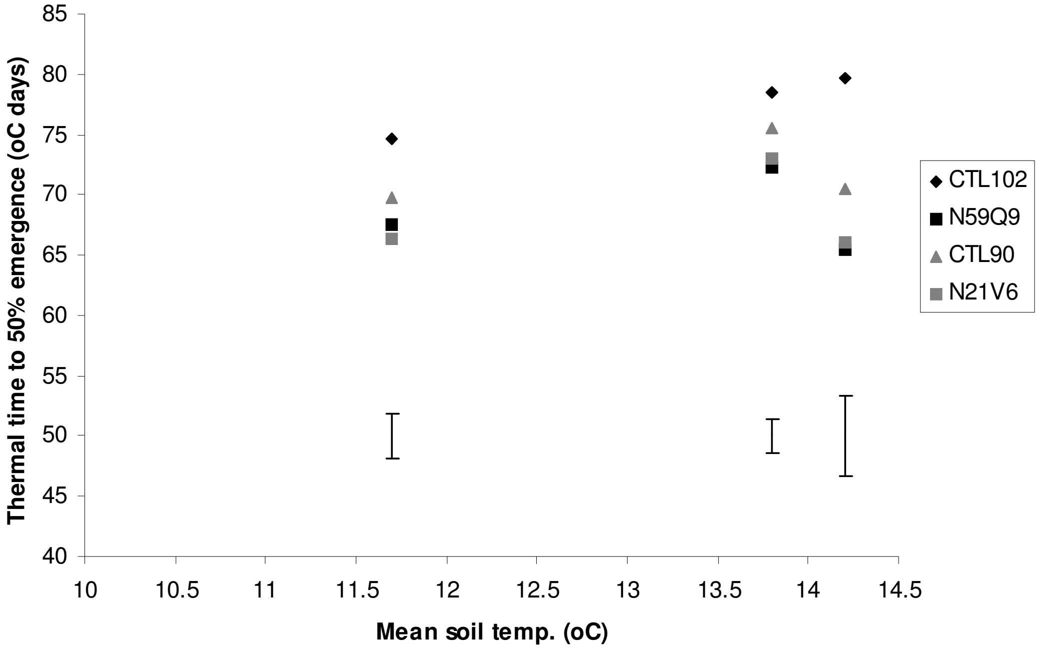


**Figure 2**. Thermal time ($^{o}$C days) between sowing and 50 % emergence (6$^{o}$ C base) against estimated mean 5 cm soil temperature ($^{o}$C) for each sowing date. (Error bars are 2 x SEM).

In all hybrids early sowing increased the time to 50 % emergence, a result of lower soil temperatures, which increase the time, required for germination and decrease the rate of shoot elongation (Blacklow, 1972). On the other hand the rate of growth of maize coleoptiles at these temperatures (about 2.5 cm $d^{-1}$) suggests that any variation in seedling emergence as a result of uneven seed depth was likely to have been minor (Alessi and Power, 1971). The mean reduction in emergence time with increasing soil temperature between the first and third sowings (1.5 days $^{o}C^{-1}$) was higher than reported by Stone *et al.* (1999) (1.0 day $^{o}C^{-1}$). This difference may be a consequence of the relatively small soil temperature range (2.5 $^{o}$C) in the current study compared with that of Stone *et al.* (1999) (18.3 to 25.2 $^{o}$C). Their study also involved varying soil temperature artificially rather than sequential sowing. Many factors, including hybrid and seedbed condition (Hayhoe *et al.*, 1996), can influence maize emergence.

There was a sowing date effect on the shape of the emergence curves, which is reflected in the *b* coefficients (Table 4). Coefficients for curves from the third sowing date were lower than those from earlier sowing in all hybrids apart from CTL102. This means that the slope of the line at the flex point was lower and indicates reduced early emergence. After the third sowing some crusting of the soil surface was noticeable, undoubtedly a consequence of prolonged exposure to above average rainfall (Table 2) without protective vegetation. Compacted soil can impede emergence of maize coleoptiles (Weaich *et al.*, 1996). The reduction in the 28 d seedling dry weight at the third compared with second sowing (Table 3), despite higher soil temperatures and a shorter time to 50 % emergence, also suggests such a limitation.

Among the hybrids emergence was consistently slower in CTL102. This may be associated with the relatively low early growth rating of this hybrid (highest early growth score, Table 1), which is reflected in a low seedling dry weight at 28 d (Table 3). In this study there was a strong negative correlation ($r = -0.85$) ($p = 0.0005$) between the 28 d seedling dry weight and time (d) to 50 % emergence. Rapid emergence has been shown to be positively correlated with early maize growth (Matthews and Hosseini, 2006) making it a useful indicator of cold tolerance (Hope *et al*., 1992). The other leafy hybrid in this study (CTL90) also displayed relatively slow emergence at all sowing despite being highly rated for early growth (low early vigour score). It is possible that the poor cold test germination in this hybrid negatively influenced seedling emergence (Matthews and Hosseini, 2006). Leafy hybrids have shown good seedling emergence traits in cool environments (Begna *et al*., 2001).

**Table 3.**

| | Seedling count | Emergence* | Weight at 28 d (g) |
|---|---|---|---|
| Hybrid | | | |
| CTL90 | 41.4 | 89.1 | 1.62 |
| CTL102 | 43.6 | 96.8 | 1.42 |
| N59-Q9 | 45.3 | 103.0 | 2.07 |
| N21V6 | 46.9 | 95.7 | 2.16 |
| Significance | < 0.0001 | < 0.0001 | < 0.0001 |
| LSD | 1.75 | 3.8 | 0.22 |
| Sowing | | | |
| 1 | 43.6 | 94.4 | 1.03 |
| 2 | 44.3 | 96.0 | 2.35 |
| 3 | 45.3 | 98.4 | 2.08 |
| Significance | NS | NS | < 0.0001 |
| LSD | | | 0.19 |

*Ratio of seedling number and seed sown after correcting for laboratory germination.

Hybrid differences in thermal time to 50 % emergence (Figure 2) are potentially quite significant in low temperature environments because thermal time accumulates slowly, resulting in significant delays in emergence (Wilson *et al*., 1995). Delayed emergence can significantly reduce maize yields, as a result of a delay in the achievement of maximum leaf area index and reduced solar radiation interception (Stone *et al*., 1999). Knowledge of hybrid differences in thermal time requirements between sowing and emergence is important to adequately model crop development and yield of maize (Wilson *et al*., 1995)

The optimum base temperature in this study was 6 $^{o}$C. This is in agreement with some studies, where estimates of base temperature were based on minimisation of the CV, (Bonhomme *et al*., 1994) but counter to others, which found the most appropriate base temperature was 8.0 $^{o}$C (Muchow *et al*., 1990; Fletcher and Moot, 2003). Appropriate base temperature may vary according to the calculation method (Bonhomme *et al*., 1994) and hybrid. Hybrids selected for cool temperate environments may have a relatively low base temperature (Frei, 2000). Another possible explanation may be that whereas most studies are defining a base temperature over sowing to silking or silking to blacklayer periods, the current study was limited to the period between sowing and emergence. Different developmental phases in maize may also have different base temperatures depending on the key physiological processes associated with each phase (Padilla and Otegui, 2005).

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**Table 4.** Coefficients of regression for the Gompertz functions for each sowing (Figure 1) where ***a*** indicates the upper asymptote value, ***b*** slope at the flex and ***c*** calendar time (days) to 50 % emergence. Numbers in parentheses = SE.

| Hybrid | ***a*** | ***b*** | ***c*** |
|---|---|---|---|
| | | Sowing 1 | |
| TL102 | 96.4 (1.5) | 1.45 (0.13) | 13.0 (0.043) |
| N59Q9 | 98.9 (0.7) | 2.07 (0.12) | 12.1 (0.018) |
| TL90 | 98.4 (0.9) | 1.49 (0.07) | 12.4 (0.026) |
| N21V6 | 99.1 (2.1) | 2.25 (0.53) | 11.9 (0.052) |
| | | Sowing 2 | |
| TL102 | 99.7 (5.2) | 0.89 (0.19) | 10.09 (0.16) |
| N59Q9 | 99.2 (0.89) | 2.40 (0.15) | 9.32 (0.03) |
| TL90 | 98.4 (1.64) | 1.48 (0.15) | 9.68 (0.06) |
| N21V6 | 96.9 (1.47) | 2.16 (0.22) | 9.40 (0.05) |
| | | Sowing 3 | |
| TL102 | 103 (3.2) | 0.81 (0.10) | 9.7 (0.15) |
| N59Q9 | 98.9 (2.6) | 0.96 (0.14) | 7.9 (0.11) |
| TL90 | 100.1 (3.1) | 0.65 (0.08) | 8.6 (0.12) |
| N21V6 | 97.4 (2.2) | 1.09 (0.15) | 8.0 (0.09) |