# PEA PHENOLOGY RESPONSES TO TEMPERATURE AND PHOTOPERIOD

**D.R. Wilson** and M. Robson

NZ Institute for Crop & Food Research Ltd., Private Bag 4704, Christchurch, New Zealand

*Summary.* Time from plant emergence to first flower in 5 contrasting pea cultivars was analysed in terms of node appearance rate (NAR) and node of first flower (NFF). Data were obtained from an experiment with the cultivars planted on 12 dates throughout a year. NAR responded linearly to temperature with a base of 4.5$^{o}$C for all cultivars. The response above the base differed among cultivars, ranging from 0.027 to 0.037 node/($^{o}$C day). NFF was stable for one cultivar (Massey) indicating no response to photoperiod, but it varied with planting date for the other cultivars. For Patea and Trounce, NFF was a linear function of photoperiod at node 8. For Rovar and Whero, it was an additive function of photoperiod (at the 8th and 12th nodes respectively) and temperature between emergence and the 8th and 12th nodes respectively. Thus NAR and NFF responses to temperature and photoperiod vary, and should be determined for each cultivar.

## INTRODUCTION

Peas are grown in diverse climates, and cultivars show strong sensitivity to environmental variation. Climatic adaptation and yield potential depend strongly on time of flowering and duration of growth. These characters vary among cultivars because of differences in phenological response to temperature and photoperiod (1,2,3). The genetic control of this variation is well documented (4), but its expression as responses to temperature and photoperiod is less well defined. Knowledge of these responses is important. In field peas, it provides a sound basis for selecting the most appropriate cultivars for each environment. In the process pea industry, planting and harvest can be scheduled accurately to ensure an even flow of product to processing plants during harvest.

In this paper we focus on temperature and photoperiod effects on time from plant emergence to first flower. This was analysed in terms of 2 components, node appearance rate (NAR) and node of first flower (NFF). Our hypotheses were that NAR was determined by temperature and that, in responsive cultivars, NFF was controlled by photoperiod. This approach has been used previously for peas (5) and is analagous to recent cereal phenology models which are based on descriptions of leaf appearance rate and leaf number responses to temperature and photoperiod respectively (6,7). Our objectives were to:

• determine whether NAR response to temperature could be described consistently with a thermal time model, and quantify the response for contrasting cultivars,

• identify cultivars with varying NFF, and quantify the variations in response to photoperiod.

## MATERIALS AND METHODS

Data for the analysis were obtained from an experiment in which 5 contrasting pea cultivars were planted on 12 dates during 1993-94 (Table 1) at Lincoln, New Zealand (latitude 43$^{o}$39'S, longitude 172$^{o}$30'E). The cultivars, chosen for variable maturity and sensitivity to photoperiod, were:

• Massey, Patea and Trounce - early, mid and mid-late maturing process pea cultivars (first flower usually at about 10, 13 and 15 nodes respectively from spring plantings), all determinate with apparent insensitivity to photoperiod.

• Rovar and Whero - blue and brown protein field pea cultivars; Rovar is determinate and thought to be insensitive to photoperiod whereas Whero is indeterminate, late maturing, and probably photoperiod-responsive.

Table 1. Planting, plant emergence and flowering dates, days from emergence to flowering, and mean temperature and thermal time above base temperature = 5°C (TT) from emergence to first flower for the intermediate cultivar Trounce.

| Planting | Emergence (E) | First Flower (F) | E to F (days) | $T_{mean}$, E to F (°C) | TT, E to F (°C days) |
|---|---|---|---|---|---|
| 19.10.93 | 31.10.93 | 19.12.93 | 49 | 11.6 | 321 |
| 23.11.93 | 03.12.93 | 12.01.94 | 40 | 14.7 | 388 |
| 21.12.93 | 01.01.94 | 08.02.94 | 38 | 16.4 | 434 |
| 19.01.94 | 28.01.94 | 06.03.94 | 37 | 16.1 | 412 |
| 22.02.94 | 02.03.94 | 01.05.94 | 60 | 12.6 | 454 |
| 23.03.94 | 02.04.94 | * | 138** | 7.8** | - |
| 20.04.94 | 04.05.94 | * | 106** | 6.5** | - |
| 24.05.94 | 01.07.94 | 20.10.94 | 111 | 7.6 | 313 |
| 14.07.94 | 15.08.94 | 06.11.94 | 83 | 9.4 | 364 |
| 15.08.94 | 04.09.94 | 14.11.94 | 71 | 10.2 | 371 |
| 15.09.94 | 03.10.94 | 26.11.94 | 54 | 12.1 | 381 |
| 12.10.94 | 26.10.94 | 08.12.94 | 43 | 14.1 | 391 |

* Frosted, did not reach flowering

** Emergence until observations stopped on 18 August 1994

The experiment was a split-plot design, with planting dates as the main plots and cultivars as the subplots. There were 3 replicates. Seeds were planted by hand on-the-square at 0.14 m spacings, equivalent to a population of 50 plants/$m^2$. Plot size was 2 m (14 plants) by 1.2 m (9 plants). Optimum crop management practices were used, with appropriate fertiliser, irrigation, herbicide, fungicide and insecticide applications to minimise agronomic and environmental stresses.

After plant emergence, 10 plants in the middle of each plot were tagged and subsequently monitored regularly. Frequency of observations varied from twice weekly in mid-summer to once every 3 weeks in mid-winter. Each time, the number of fully-extended nodes on each plant was recorded. The date of appearance and the number of the node of first flower were recorded for each plant. Observations continued until node appearance stopped, either as plants approached maturity or because they were frosted in autumn and early winter plantings. Daily maximum and minimum screen air temperatures were obtained from a meteorological station located 200 m from the experiment site.

## RESULTS AND DISCUSSION

### *Time from emergence to first flower*

The planting date treatments caused large differences in the time from emergence to first flower in all the cultivars because plants were exposed to a wide range of temperatures. Cultivars differed in their response to planting date, but the general effect is illustrated by the results for Trounce, which had the intermediate duration (Table 1). Thermal time above a base of 5°C, which is commonly used to describe the time to first flower in the process pea industry, averaged 383 °C days (s.d. = 42) for Trounce. Thermal time was not consistent among planting dates for any of the cultivars except Massey, suggesting that there were both temperature and photoperiod effects.

### *Node appearance rate*

For each cultivar there was a linear response of NAR to air temperature across all planting dates. The mean base temperature was 4.5°C (?0.2) with no significant difference among the cultivars. However, NAR differed significantly among cultivars. The relationships between NAR and temperature for Whero and Massey are shown in Fig.1 They had the highest and lowest slopes with values of 0.027 and 0.037 node/(°C day) respectively. Patea, Trounce and Rovar had similar intermediate slopes (0.030, 0.031 and 0.032 node/(°C day) respectively). The standard error of each slope was ?0.001, and the l.s.d. ($P<0.05$) for the comparison of slopes was 0.003. Corresponding phyllochrons above the 4.5°C base ranged from 27 (Whero) to 37 (Massey) °C days per node.

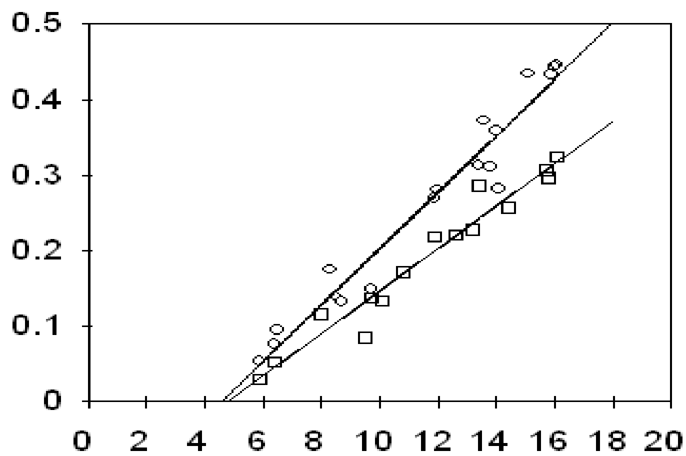


Figure 1. Relationships between node appearance rate and temperature for Massey (?) and Whero (?).

*Node of first flower*

The response of NFF to planting date differed among cultivars (Fig. 2). The NFF was stable for Massey, indicating no response to photoperiod. However, the planting date effect on NFF was significant ($P<0.05$) for all the other cultivars, with a higher node number from summer and autumn plantings suggesting a photoperiod effect.

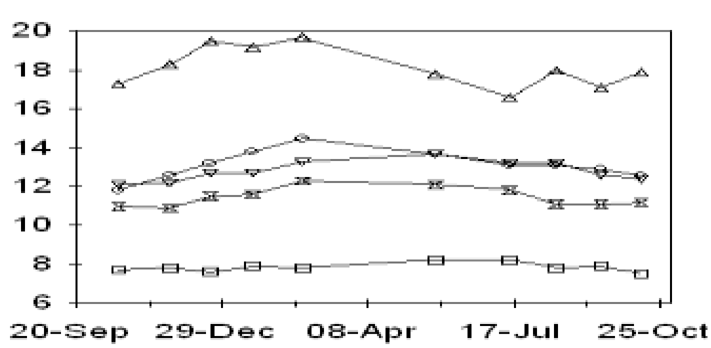


Figure 2. Response of node of first flower to planting date for Massey = ?, Patea = _, Trounce = ∇, Rovar = ?, and Whero = Δ.

The influence of photoperiod and/or temperature on NFF for the four cultivars was determined by multiple regression analysis using an additive model. Results differed among cultivars. For Trounce and Patea, NFF was a linear function of photoperiod at the time the 8th node appeared ($r^2$ = 0.74 and 0.85 respectively). For Rovar and Whero, NFF was not related only to photoperiod. For Rovar, it was an additive function of photoperiod at the time of the 8th node and of mean temperature between plant emergence and the 8th node ($r^2$ = 0.91). For Whero, NFF was also an additive function of photoperiod and temperature, at the time of the 12th node and between plant emergence and the 12th node respectively ($r^2$ = 0.78). Comparisons between NFF predicted by the regressions and observed values for the four cultivars are presented in Fig. 3.

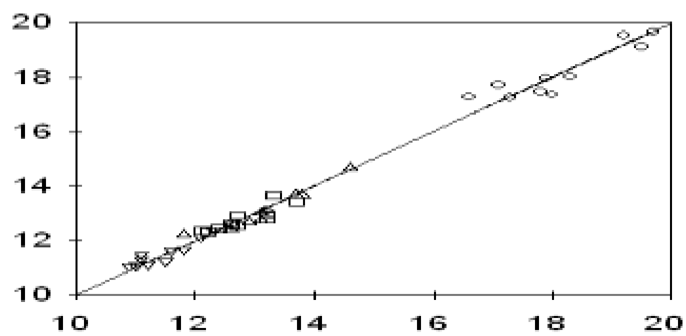


Figure 3. Comparisons between NFF predicted by the regressions and observed values for Patea (∇), Trounce (?), Rovar (Δ), and Whero (?). The solid line is the 1:1 line.

CONCLUSIONS

The thermal time approach for describing time to first flower is common in the process pea industry. Our results provide a rationale for the approach in photoperiod-insensitive cultivars such as Massey, because the NFF is constant and the NAR is a linear function of temperature. However, the NAR response to temperature varies and should be determined for each cultivar.

In addition to variable NAR, the NFF for some cultivars varies with planting date because of a response to photoperiod and also, in some cases, temperature. These cultivars need to be identified and their responses quantified, especially if they are likely to be planted in previously untested climates or outside normal planting times.

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