**Canopy development in phosphorus deficient sweet corn.**

**Andrew Fletcher**[1], Derrick Moot[1] and Peter Stone[2]

[1]Field Service Centre, P.O. Box 84, Lincoln University, Canterbury, New Zealand.
Fletcha2@Lincoln.ac.NZ, Moot@Lincoln.ac.NZ
[2]Crop and Food Research, P.O. Box 85, Hastings, New Zealand. StoneP@Crop.cri.NZ

**Abstract**

Leaf appearance rate and leaf area contribute to the interception of solar radiation in crops. An experiment was established in October 2001 at Lincoln, Canterbury, New Zealand to determine the response of these variables for 'Challenger' sweet corn to three levels of phosphorus (P)(0, 100, and 200 kg P/ha as triple super phosphate) applied to a low P fertility site (Olsen P = 6 µg/ml).

Leaf tip appearance was linearly related to cumulated thermal time (Tb, base temperature = 8?C), but the rate was reduced with phosphorus deficiency. The interval between individual leaf tips was 31.3 ?Cd (growing degree days) in the 0 kg P/ha crops and 25.8 ?Cd in the 200 kg P/ha crops. Fully expanded leaf appearance occurred exponentially against cumulated thermal time. The P deficient crops showed a reduction in fully expanded leaf appearance rate and the degree of curvature of the exponential function was reduced.

The area of each leaf was used to construct leaf area profiles, related to leaf position on the plant. Profiles showed a peaked distribution with leaves 11 and 12 having the greatest area at 415 $cm^2$ in the 0 kg P/ha treatment and 570 $cm^2$ in the 200kg P/ha crops.

In conclusion, phosphorus deficiency affected both individual leaf size and leaf appearance rate. Both of these variables need to be considered when constructing models of canopy development for sweet corn.

**Keywords**

phosphorus, leaf appearance, leaf area, canopy development, sweetcorn, *Zea mays*.

**Introduction:**

Research with sweet corn (*Zea mays* L.) has indicated an increase in marketable yield with fertiliser P (10. 11), and shown that sweet corn may be more responsive to P than maize (1). However, there is little quantitative data on the mechanisms by which sweet corn yield is reduced by P deficiency.

In the absence of stress, crop yield is limited by the interception of solar radiation (RI) (3,4). In maize RI in response to P deficiency has been shown to be more important than the efficiency with which it is used for growth (7). Reduced P availability may alter RI and decrease yield by influencing canopy development as described by leaf appearance rate and individual leaf area.

The objective of this experiment was to investigate the component processes (leaf appearance rate and individual leaf area) of sweet corn canopy development under varying P supply.

**Materials and Methods:**

In October 2001, plots were established in a randomised complete block design with three replicates, on a P deficient soil (Olsen P = 6 µg/ml). Treatments were 0, 100 and 200 kg P/ha applied as triple superphosphate (0: 21: 0: 0) in split applications on 5$^{th}$ and 14$^{th}$ October and incorporated to 15cm depth. Plots were then hand sown to sweet corn ('Challenger') on 25$^{th}$ October at 71,000 plants/ha. Basal applications of sulphur (S)(35 kg S/ha as $K_2SO_4$) and nitrogen (N) (100 kg N/ha as calcium ammonium nitrate) were applied to the crops on 15$^{th}$ October, 20$^{th}$ December, and 16$^{th}$ January.

Crops were fully irrigated, with herbicides and pesticides applied as necessary for weed and pest control.

Leaf tip and fully expanded leaf (ligule visible) numbers were recorded from five marked plants per plot, twice weekly. Leaf area profiles relating leaf position to individual leaf area were constructed by destructive measurements of individual leaf areas on 7th and 30th December 2001, and 14th February 2002.

Thermal time (**Tt**, with a base temperature of 8?C) after emergence was calculated from mean daily temperature data recorded at Broadfields meteorological station (located 1km south of the experimental site). The phyllochron for leaf tip appearance was calculated as the inverse of the slopes of linear regression (forced through the origin) between leaf tip appearance and cumulative Tt. Fully expanded leaf appearance was exponentially related to Tt (5) (Equation 1). The relationship between leaf position and individual leaf area was fitted using the method of Dwyer and Stewart (2), (Equation 2). All curves were fitted for individual plots and parameters were tested using one-way analysis of variance.

$$LN = ae^{(bTt)} \qquad \textbf{Equation 1}$$

$$Y = Y_0 \exp[-c(X - X_0)^2 + d(X - X_0)^3] \qquad \textbf{Equation 2}$$

**Results:**

*Leaf appearance rates:*

Leaf tip appearance was linearly ($R^2$≥0.89) related to thermal time, but was delayed by P deficiency (Figure 1a). The phyllochron for leaf tip appearance was not different for the 200 kg P/ha (25.8 ?Cd/leaf tip) and 100 kg P/ha (27.4?Cd/leaf tip) crops but increased (*P*<0.01) markedly to 31.3 (?Cd/leaf) without P applied (Table 1).

Fully expanded leaf appearance was exponentially (Equation 1) related ($R^2$>0.97) to thermal time, and was delayed by P deficiency (Figure 1b). There was no difference (p=0.66) in the intercept (**a**, mean was 2.13) of these curves, but curvature (**b**) decreased with P deficiency (Figure 1b). from 3.5?$10^{-3}$ for 100 and 200 kg P/ha crops to 3.0?$10^{-3}$ for the control crops (Table 1).

**Table 1. Coefficients for leaf appearance parameters for 'Challenger' sweet corn grown with 0, 100 and 200 kg P/ha, in Canterbury, New Zealand. Phyllochron (for leaf tip appearance, calculated from Figure 1a, $^{o}$Cd/leaf tip); a and b (for fully expanded leaf appearance, Equation 1).**

| kg P/ha | Phyllochron | a | b |
|---|---|---|---|
| **0** | 31.3 | 2.15 | 3.00?$10^{-3}$ |
| **100** | 27.4 | 2.08 | 3.47?$10^{-3}$ |
| **200** | 25.8 | 2.17 | 3.50?$10^{-3}$ |
| **P value** | 0.007 | 0.656 | 0.017 |

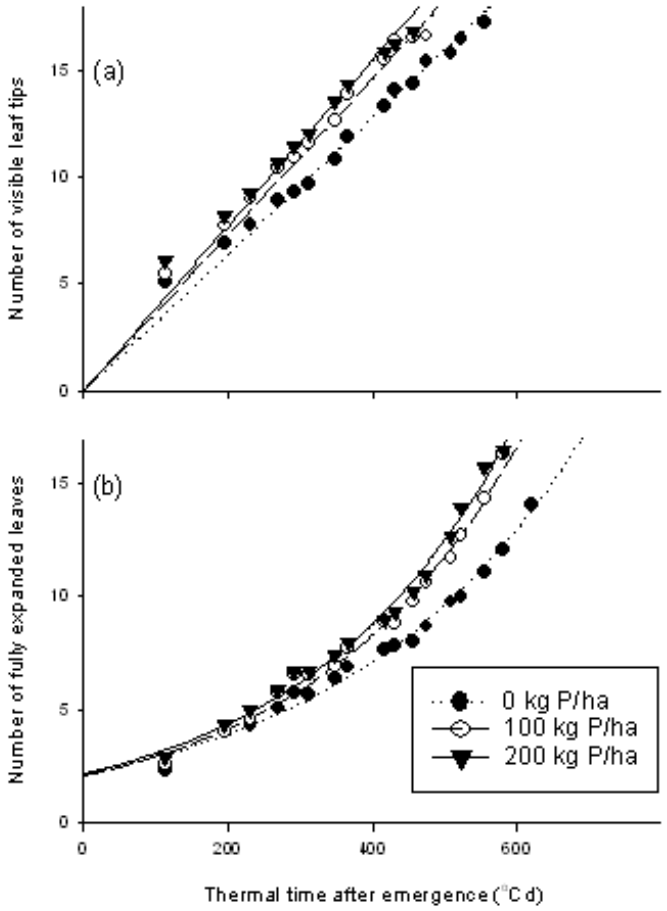


**Figure 1. Leaf tip (a) and fully expanded leaf (b) appearance rates at three levels of applied P (0, 100 and 200 kg P/ha) for sweet corn crops grown in Canterbury, New Zealand.**

*Individual leaf area:*

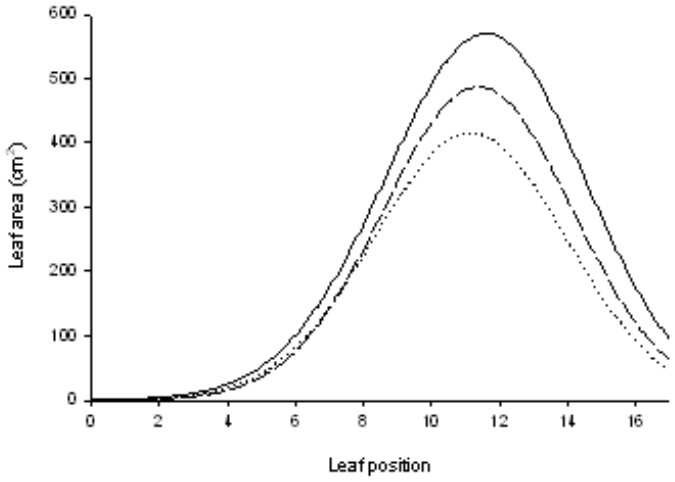


**Figure 2. Individual leaf area against main stem leaf position for, 'Challenger' sweet corn grown with 0 (· · · · · · · ), 100 (-------) and 200 (□□) kg P/ha, grown in Canterbury, New Zealand.**

Individual leaf area was related ($R^2$=0.99) to leaf position using a peaked function (Equation 2) as described by Dwyer and Stewart (2). Individual leaf area of the largest leaf ($\mathbf{Y_0}$) increased ($p<0.05$) from 415$cm^2$ to 570 $cm^2$ when applied P increased from 0 to 200 kg P/ha. The position of the peak ($\mathbf{X_0}$) was consistent between leaf 11 and 12 and the two parameters describing the shape of this function (**c, d**) were unaffected by P level (Table 2).

**Table 2. Coefficients for three P treatments (0,100, 200 kg P/ha) relating leaf area to leaf position (Equation 2) in 'Challenger' sweet corn grown in Canterbury, New Zealand.**

| kgP/ha | $Y_0$ | C | $X_0$ | D |
|---|---|---|---|---|
| **0** | 415 | 0.0625 | 11.15 | -0.00030 |
| **100** | 487 | 0.0647 | 11.38 | -0.00143 |
| **200** | 570 | 0.0584 | 11.61 | -0.00060 |
| **α value** | 0.02 | 0.69 | 0.33 | 0.52 |

**Discussion:**

P deficiency in sweet corn reduced both leaf tip and fully expanded leaf appearance (Figure 1a,b). The value of the phyllochron (26?Cd) in the fully fertilised crop was similar to that reported by Rogers *et. al.* (8) for sweet corn (25?$^{o}$Cd). Stem elongation and hence the curvature of the response of fully expanded leaves to Tt, was reduced by P deficiency. The reductions in both leaf appearance and individual leaf area have previously been reported for maize (6) and have been shown to reduce cumulative RI (7).

Leaf appearance is a development process that is mainly affected by temperature and photoperiod. However in the current experiment, P deficiency decreased leaf appearance rates. Two crop growth processes, either a reduced rate of initiation of leaf primordia (plastochron) or the rate at which the primordia extend, may be responsible for this decrease. In wheat the effect may be attributed to a combination of this processes (9). Further research is ongoing to determine the response of the plastochron of sweet corn crops to P deficiency.

Both leaf appearance rate and individual leaf area are important components determining RI and both were markedly reduced by P deficiency. In future models of sweet corn P response, effects on both these components need to be included. To do this both leaf appearance rate and individual leaf area need to be related to soil or plant factors. This will allow better simulations of RI and hence growth. However, effects on radiation use efficiency also need to be considered. Previous studies have indicated that radiation use efficiency in maize is unaffected by P availability (7). This requires further quantification for sweet corn.

**Conclusions:**

Both individual leaf area and leaf appearance rate in sweet corn were reduced by P deficiency. Both variables need to be considered in subsequent models of the effect of P availability on sweet corn growth and yield.

**References:**

(1) Bole, J.B. and Freyman, S. (1975) Can. J. Soil Sci., 55:137-143

(2) Dwyer, L.M. and Stewart, D.W. (1986) Agron. J., 78:334-343

(3) Gallagher, J.N. and Biscoe, P.V. (1978) J. Agric. Sci., Camb., 91:47-60

(4) Monteith, J.L. (1977) Philos. Trans. R. Soc. London B, 281:277-294

(5) Muchow, R.C., Sinclair, T.R. and Bennett, J.M. (1990) Agron. J., 82:338-343

(6) Plenet, D., Etchebest, S., Mollier, A. and Pellerin, S. (2000a) Plant Soil, 223:117-130

(7) Plenet, D., Mollier, A. and Pellerin, S. (2000b) Plant Soil, 224:259-272

(8) Rodriguez, D., Pomar, M.C., Goudriaan, J. 1998. Plant Soil, 202:149-157

(9) Rogers, B., Sorensen, I.B. and Stone, P.J. (1999) Proc. Annu. Conf. Agron. Soc. NZ., 29:87-90

(10) Sanchez, C.A., Burdine, H.W.and Martin, F.G. (1989) J. Fert. Issues., 6:17-24

(11) Sanchez, C.A., Porter, P.S. and Ulloa, M.F. (1991) Soil Sci. Soc. Amer. J., 55:871-875