Effect of sowing time on yield of a short and a long season maize hybrid

Isabelle Sorensen, Peter Stone and Brian Rogers

New Zealand Institute for Crop & Food Research PO Box 85 Hastings, New Zealand

Abstract

The effects of sowing time on maize yield were examined: 1) to test the hypothesis that maximum yield occurs when the time of maximum green leaf area index (GLAI) coincides most closely with the time of maximum incident solar radiation (SR) and 2) to use the results of this test to develop simple rules of thumb to help growers optimise maize sowing time. Two maize hybrids which differed in time required for maturation, short season (Elita) and long season (32H39) were sown at approximately fortnightly intervals from 21 September 1999 to 20 January 2000, giving a total of ten sowing times. Canopy development was monitored weekly and grain yield was measured at maturity. For the long season hybrid, grain yield was maximised when there was close synchrony between times of maximum GLAI and SR. For long season hybrids in New Zealand, maximum yield will occur when maximum GLAI occurs close to Christmas Day. For the short season hybrid, grain yield was maximised when maximum GLAI occurred 11 days after peak SR. We conclude that, for short season hybrids in New Zealand, maximum yield will occur when maximum GLAI occurs around New Year's Day.

Additional key words: Zea mays, *solar radiation, maximum green leaf area*

Introduction

Given an appropriate sowing time, long season hybrids of maize yield more than short season hybrids and it seems that this is related to the amount of solar radiation intercepted by the crop canopy (Biscoe and Gallagher, 1977). But what is an 'appropriate' sowing time, and does it differ for long and short season hybrids? If so, can this difference be related to solar radiation levels?

The amount of solar radiation (SR) received at the Earth's surface follows the same pattern year after year and can be described using a sine wave. Its wavelength is the same anywhere on the planet, and it is only the amplitude that varies between locations. Using Gisborne as an example (Fig. 1), the lowest point of the SR curve occurs around 21 June (the shortest day of the year) and the highest point occurs around 21 December (the longest day of the year), or close to Christmas Day. These dates are adhered to throughout the Southern Hemisphere. Previous experiments have shown that radiation interception by maize is closely related to crop growth and yield (Muchow *et al.*, 1990; Wilson *et al.*, 1995). Related to this, we have developed the hypothesis that yield appears to increase when the time of maximum

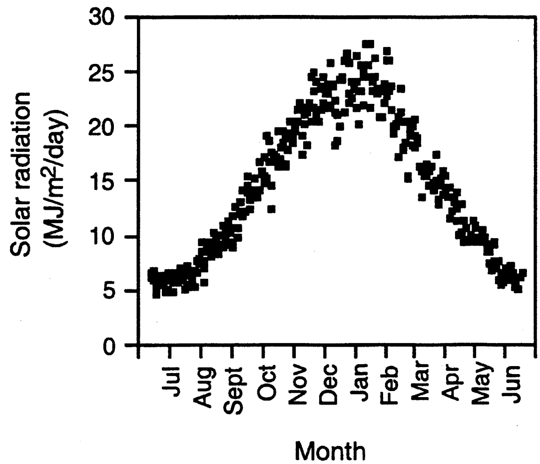

Figure 1. Time course of solar radiation, Gisborne, 30 year average.

green leaf area index (GLAI) coincides most closely with the time of maximum incident radiation (Stone *et al.*, 1999).

This hypothesis was developed as a result of a study designed to demonstrate the effect of soil temperature on development and growth of maize. As soil temperature increased so did rate of crop and canopy development and, with them, biomass and yield. Soil temperature, however, did not influence the size of GLAI (integral of LAI with time), so the beneficial effects of soil temperature were caused only by variation in the pattern of canopy development. It became evident that increased soil temperature increased radiation interception and, hence, biomass and yield because, by increasing the rate of canopy development it provided for a closer synchrony between time of peak radiation interception (maximum LAI) and peak radiation incidence (maximum SR).

Following the development of this hypothesis, it then needed to be tested directly. The purpose of this experiment was to determine if maize yield can be maximised by synchronising the time of peak LAI with time of peak SR. Can we then use this information to develop rules of thumb that help farmers to optimise sowing time for maize hybrids of differing season length?

Materials and Methods

The experiment was performed in a cool-temperate climate in Hawke's Bay, New Zealand (lat. 39.47°S, long. 176.64° E) where temperature and radiation during the maize growing season average *ca* 15.6 °C and 16.1 $MJ/m^2/d$, respectively. During the experimental period (21 Sept 1999 to 30 June 2000) the daily average temperature minima and maxima were 9.6 and 21.1°C, respectively.

Two maize hybrids of different maturity (Elita, short, 77 comparative relative maturity (CRM) and 32H39, long, 114 CRM) were sown at approximately fortnightly intervals from 21 September 1999 to 20 January 2000, giving a total of ten sowing times: 21 Sept, 29 Sept, 11 Oct, 27 Oct, 9 Nov, 23 Nov, 8Dec, 21 Dec 1999 and 6 Jan and 20 Jan 2000.

Seeds were hand planted at 5 cm depth, with an inter-row spacing of 70 cm and an intra-row spacing of 16 cm, giving a plant population of *ca* 90,000 plants/ha. Plots were 9 x 15 m. Hybrids (sub-plots) were randomly assigned within sowing times (main plots) which were fully randomised within the trial area. There was no replication of each combination of hybrid and sowing time. Fertiliser was applied prior to planting at a rate of 200 kg N/ha (as urea) and 100 kg P/ha (as triple superphosphate). Irrigation was applied when PET reached 80 mm from the previous irrigation.

Five tagged plants were observed weekly and the times of leaf tip appearance, full leaf expansion and leaf senescence were recorded. Time of maximum green leaf area index (GLAI) is assumed to have coincided with the appearance of the last fully expanded leaf, as usually occurs in *Zea mays* (Stone *et al.*, 2000). At maturity, crop yield was measured on 30 plants per plot, selected from 15 contiguous plants within each of the two central rows of each plot. Cobs were stripped of kernels using a 'Ransomes' automated sheller and the fresh mass of kernels was recorded. Dry mass was measured on sub-samples that were placed in a fan-forced oven at 75 °C until constant mass was achieved. All yields are reported on a 14% moisture basis. Data were analysed by simple linear regression using the 'Statview' package (BrainPower Inc., Calabasas, CA, USA).

Results and Discussion

Sowing time had a major influence on the relationship between time of peak SR and maximum GLAI, such that any delay in sowing reduced the synchronisation of peak SR and maximum GLAI for both hybrids.

For the long season hybrid, the first sowing (L1) reached maximum GLAI when SR was at a maximum (23 MJ/m^2/day) (Fig. 2). The fifth sowing (L5) attained its maximum GLAI 39 days after peak SR, at which time SR had decreased by 7%, to 21.5 MJ/m^2/day. The tenth sowing (L10) did not attain maximum GLAI until 114 days after peak SR, when SR had dropped to 50% of its maximum (11.5 MJ/m^2/day). As expected, the interval between peak GLAI for L1, L5 and L10 increased with time because average temperature declined as the experiment progressed.

For the short season hybrid, the first sowing (S1) attained maximum GLAI when SR was 22.5 MJ/m^2/day, just before its peak. The fifth sowing (S5) reached maximum GLAI 27 days after peak SR, but when SR was still close to its maximum (22 MJ/m^2/day). For the tenth sowing (S10), maximum GLAI occurred 97 days after peak SR, by which time SR had dropped to 60% of its maximum value (13.5 MJ/m²/day). As with the long season hybrid, the interval between peak GLAI for S1, S5 and S10 increased because average daily temperature declined with time.

As a consequence of these relationships between GLAI and SR the early sown crops of the long season hybrid would have absorbed more radiation than the late sown crops. This is likely to have been responsible for the strong linear relationship between yield and the time at which the maximum GLAI occurred (Fig. 3). For the first nine sowings of the long season hybrid, yield declined by 152 (±9 s.e.) kg/ha for every day for which peak SR and GLAI were out of synchronisation (r^2=0.97; P<0.0001). No yield was recorded for the final sowing. Yield declined at an increasing rate as sowing time was delayed, as a consequence of the increase in the interval from sowing to maximum GLAI for each successive sowing (data not shown).

For the short season hybrid, relationships between sowing time, peak GLAI and peak SR were not quite as simple. Synchronisation of peak SR with peak GLAI did not result in maximum yield as it did in the long season hybrid. Why might this have occurred?

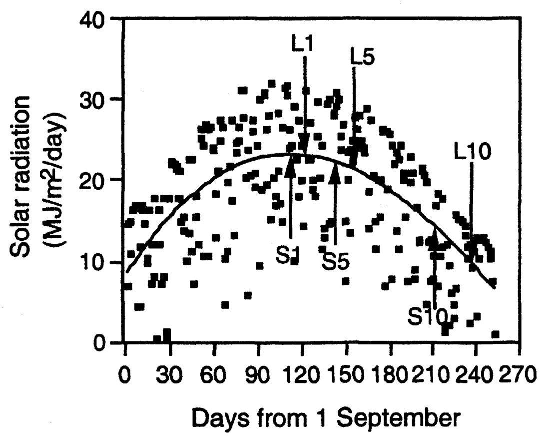

Figure 2. Time course of solar radiation during the experimental period, Hastings, September 1999 to June 2000. Arrows show time at which maximum GLAI occurred for sowing 1, 5 and 10 of the short season (S) and long season (L) maize hybrids, respectively.

The answer is probably related to the fact that, while the first sowing reached peak GLAI at peak SR, it spent a proportionately longer period of canopy duration at a low level of SR than, for instance, sowing 5. The upper arrows on Fig 4. show the time of sowing (left arrow) and the time of maximum GLAI (right arrow) for S1. The lower pair of arrows shows corresponding data for S5.

For S1 much of the advantage of reaching maximum GLAI at peak SR may have been lost through spending most of its canopy development at a time of comparatively low SR. During the sowing to maximum GLAI period SR averaged 18 MJ/m²/day, with a total incident amount of 1638 MJ/m² for the 91 days of crop growth. S5, by contrast, also reached maximum GLAI close to peak SR but had the advantage of spending its time of canopy development at a higher average SR. For S5, the daily SR averaged 23 MJ/m², with an incident total of 1656 MJ/m² during its 72 days of crop growth.

While the incident radiation in the sowing to maximum GLAI period was very similar for the S1 and S5 treatments, the more rapid attainment of maximum

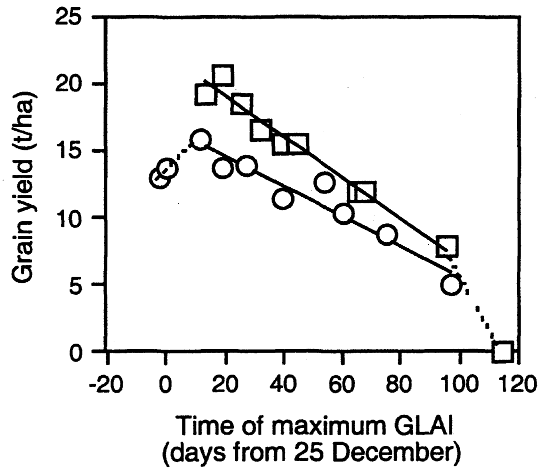

Figure 3. Relationship between maize grain yield and occurrence of maximum GLAI. □ short season hybrid; ○ long season hybrid. Solid lines show simple linear relationships, hatched line shows undefined relationships. Data are plotted against days from 25 December for ready reference to rules of thumb

GLAI in the latter treatment (72 compared with 91 days) will have enabled it to intercept a higher proportion of that radiation. This probably explains the 0.8 t/ha yield difference between the first and fifth sowings, and is likely to be borne out in subsequent canopy analyses.

As a consequence of these phenomena, there was no simple relationship between grain yield and time of maximum GLAI for the earlier (S1-S3) sown crops of the short season hybrid. For later sown (S3-S10) crops, however, yield declined by 110 (±13 s.e.) kg/ha for every day for which peak SR and GLAI were out of synchronisation (r^2=0.92; P<0.0001).

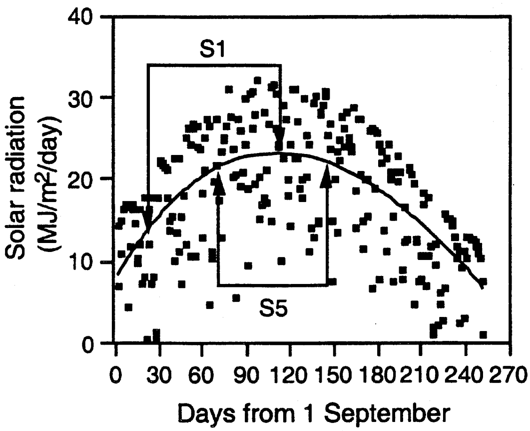

Figure 4. Time course of solar radiation during the experimental period, Hastings, September 1999 to June 2000. For each pair of arrows, left arrows show sowing time and right arrows show occurrence of maximum GLAI. S1 and S5 are first and fifth sowings, respectively, of the short season maize hybrid.

Conclusions

The relative timing of maximum SR and maximum GLAI had significant implications for crop yield. For a long season maize hybrid, achieving a full crop canopy close to peak SR maximised yield. From this we propose a simple rule of thumb: for maximum yield sow long season hybrids to achieve maximum GLAI around Christmas. These results suggest that yield will decline by *ca.* 150 kg/ha for every day for which peak SR and GLAI are out of synchronisation. For a short season maize hybrid, maximum yield was achieved when maximum GLAI occurred 11 days after peak SR. From this we propose another rule of thumb: for maximum yield, sow short season hybrids to achieve maximum GLAI around New Year's Day. After that time, these results suggest that yield will decline by *ca* 110 kg/ha for every additional day for which peak SR and GLAI are out of synchronisation. While these rules of thumb are 'retrospective' in that one doesn't know at sowing when maximum GLAI will occur, growers can assess the extent to which the sowing of a given crop was 'early' or 'late' and make iterative adjustments in subsequent seasons. Clearly, growers will need to take into account site-specific risks associated with factors such as frost before adopting these preliminary rules of thumb, particularly for very early sowings.

References

Biscoe, P.V. and Gallagher, J.N. 1977. Weather, dry matter and yield. *In* Environmental Effects on Crop Physiology (ed. J.J. Cutting and C.V. Landsberg), pp. 75-100. Academic Press, London.

Muchow, R.C, Sinclair, T.R. and Bennett, J.M. 1990. Temperature and solar radiation effects on potential maize yield across locations. *Agronomy Journal 82*, 338-343.

Stone, P.J., Sorensen, I.B. and Jamieson, P.D. 1999. Effect of soil temperature on phenology, canopy development, biomass and yield of maize in a cool-temperate climate. *Field Crops Research 63*, 169-178.

Stone, P.J., Wilson, D.R., Jamieson, P.D. and Gillespie, R.N. 2000. Water deficit effects on sweet corn. *Australian Journal of Agricultural Research* (in press).

Wilson, D.R., Muchow, R.C. and Murgatroyd, C.J. 1995. Model analysis of temperature and solar radiation limitations to maize potential productivity in a cool climate. *Field Crops Research 43*, 1-18.