Effect of sowing time on sweet corn yield and quality

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Abstract

The effects of sowing time on sweet corn yield and quality were examined by sowing three sweet corn (*Zea mays* L.) hybrids of varying maturity at approximately fortnightly intervals from 21 September 1999 to 20 January 2000. Delayed sowing reduced total crop biomass by 0.86 t/ha per 10-day delay. Harvestable ear yield declined by 1.6 t/ha per 10 day delay in sowing, mainly through reduced mass of harvestable secondary ears. Effects of sowing time on primary cob characters such as length, kernel fill and diameter were minor. There was no consistent effect of sowing time on kernel colour, which differed significantly among hybrids. Kernel toughness was the only component of yield or quality to benefit from a delay in sowing, with kernels becoming more tender in later-sown crops. The effects of genotype on kernel toughness were at least as great as those of sowing time. Given the yield penalty incurred through delayed sowing, it seems likely that quality targets will be more profitably met by careful choice of hybrid than by choice of sowing time. The implications of these findings for improved crop management are briefly discussed.

Additional key words: Zea mays, *hybrids, colour, kernel toughness*

Introduction

Sowing time is the most powerful tool that growers possess for altering the crop environment. It is the major method by which they can influence a crop's exposure to the solar radiation and temperature needed to drive growth and development.

In a previous study with *Zea mays* L. (grain maize), biomass and yield were maximised when the time of peak radiation interceptance (maximum LAI) was synchronised with the time of peak radiation incidence (around the summer solstice) (Stone *et al.* 1999). In that study, the time of peak LAI was manipulated by altering soil temperature, a method that is not practicable for growers. A much more simple and economical method to achieve the same end is to choose an appropriate time of sowing.

Harvestable or process yield is currently the primary determinant of crop value, although for some markets quality characteristics are also important. High cob length, fill and diameter are valued traits for most end-uses, but most particularly the fresh and pouched corn markets. A high degree of 'depth' or 'yellowness' of kernel colour is a generally desirable trait in sweet corn sold fresh, canned, frozen, pouched or powdered. Despite a general consumer preference for more 'yellow looking' kernels, there are currently no objective standards for colour used by sweet corn marketers or processors. We examined kernel colour using the widely used CIELAB scale, with the aim of establishing some colour benchmarks for producers, processors and marketers. Similarly, while kernel toughness has been identified as a common source of consumer dissatisfaction with sweet corn, objective standards are not applied to measure it, except in breeding programmes. We examined kernel pericarp toughness using a penetrometer, again with the aim of establishing benchmark values for this value-related parameter.

We therefore examined the influence of sowing time on yield and quality of sweet corn. Our main aim was to provide growers and processors with the basic information needed to maximise the value of their crops.

A subsequent publication will examine the mechanisms by which sowing time affects sweet corn yield and quality.

Materials and Methods

Site

The experiment was performed in a cool-temperate climate at Hastings, New Zealand (lat. 39.47° S, long.

176.64° E) where long-term average temperature and radiation during the experimental period (21 September-16 May) are 15.6°C and 16.1 MJ/m^2/d, respectively. In the 1999-00 growing season, daily average temperature minima and maxima were 9.6 and 21.1°C, respectively, and soil temperature at 10 cm depth averaged 19.5°C. Solar radiation averaged 18.4 MJ/m^2/d. The soil was a Mangateretere silt loam (*Typic Haplaquept*) of *ca* 0.6 m depth which overlies a clay subsoil.

Soil nutrient levels were measured to a depth of 15 cm before planting. Values for the experimental area were: available (mineralisable) N 92 kg N/ha; Olsen P 26 µg/ml; exchangeable K 0.9 meq/100 g; exchangeable Ca 14 meq/100 g; exchangeable Mg 2.7 meq/100 g; exchangeable Na 0.2 meq/100 g; pH 6.2.

Crop culture

Sweet corn was grown in rows 0.7 m apart with 0.24 m between plants within rows. Two seeds per position were sown using jab planters, and plots were thinned following emergence to give a uniform population of 59,500 plants/ha. Plots were 15 x 4.2 m.

Fertiliser was applied and incorporated prior to sowing at the rate of 200 kg N/ha as urea and 30kg P/ha as triple superphosphate. Weeds were controlled by pre-plant incorporation of 'Trophy' at 5 l/ha (2 kg/ha acetochlor) mixed with 'Gardoprim' at 1 l/ha (0.5 kg/ha terbuthylazine). Plots were irrigated when estimated crop ET reached 80 mm from the last irrigation.

Treatments

Three hybrids of varying maturity (Sheba, Challenger and XP1029; early, mid and late, respectively) were sown at approximately fortnightly intervals beginning on 21 September 1999 and finishing on 20 January 2000. Hybrids (sub-plots) were randomly assigned within sowing times (main plots) which were fully randomised within the trial area. There was no replication for each combination of sowing time and hybrid.

Crop measurements

At maturity, yield was measured on 25 contiguous plants harvested from a single row selected randomly from one of the four inner rows of each plot. Total ear fresh mass and number were determined from primary, secondary and other ears prior to separation on the basis of suitability for processing. Ears were deemed 'harvestable' (suitable for processing) if wider than 4 cm or longer than 15 cm. From this fraction of the total a number the random subsamples were taken.

The numbers of kernel rows, kernels per row and unfilled florets per ear were measured on a 10 ear subsample from which cob length, unfilled cob length and cob diameter (maximum) were also measured. Following this, the fresh masses of husk, rachis and kernel (stripped using a 'Key' commercial stripper) were measured before determining component dry matter using a further subsample, dried in a fan-forced oven at 80 °C until constant mass was attained.

Kernel colour and pericarp toughness were measured on a 10 ear subsample, which was divided into two equal groups: fresh and cooked. Cooked cobs were plunged into 10 l of rapidly boiling water for 5 minutes before being cooled to ambient temperature in running water (10 °C). Kernel colour was measured at *ca* 25, 50 and 75% length intervals on intact cobs with a Hunterlab Miniscan XE, using the CIELAB colour scale (Anon., 1996). Ten readings were made on each of the five fresh and cooked cobs from each subsample. Following colour measurement, pericarp toughness was measured at 3-cm intervals along opposite sides of intact cobs, from the base of the cob to the last developed kernel. Toughness was measured as the force required to puncture the pericarp of individual kernels with a steel rod of 2.38 mm diameter. A Chatillon DFG10 Digital Force Gauge (set to record maximum force) was attached to the tailstock of a Myford Super 7 lathe to provide a load cell speed of 5 cm/min. Maximum force occurred at the point of pericarp puncture, and was divided by the cross-sectional area of the rod to obtain a standard measure of pericarp toughness (g/mm^2). Pericarp toughness varied systematically and significantly along the ear (data not shown), and data presented here are from kernels in the middle of the cob. Responses of kernel colour and toughness to sowing time were similar for fresh and cooked cobs. Only data for cooked cobs are presented.

No quality analyses were undertaken on secondary or other ears. Fresh masses of husk, rachis and kernel (stripped using a 'Key' commercial stripper) were measured before determining component dry matter of a subsample, dried in fan-forced oven at 80 °C until constant mass was attained.

Kernel recovery was calculated as stripped kernel fresh mass from all harvestable ears as a proportion of total ear mass. Processors of corn kernels aim for maximum kernel recovery.

Fresh masses of non-harvestable primary, secondary and other ears were recorded. No yield component or quality analyses were undertaken on these ears.

Total above-ground crop biomass was determined using the fresh mass of 10 whole plants and the dry mass of leaf, stem and tillers obtained from a 3-plant sub-sample, dried in a fan-forced oven at 80 °C until constant mass was attained. Husk, kernel and rachis dry masses were obtained from the ear harvests outlined above.

Data were analysed by simple linear regression, using the 'Statview' package (BrainPower Inc., Calabasas, CA, USA).

Results

Crop biomass of all hybrids declined as sowing was delayed, by an average 0.86 t/ha for each 10 day delay in sowing (Fig. 1). As expected, biomass increased as hybrid maturity lengthened.

Harvestable ear yield declined *ca* 1.6 t/ha for each 10 day delay in sowing ($P<0.01$), with a slightly greater reduction for the latest sowing time (Fig. 2). There was no significant yield difference among hybrids. For all hybrids, the proportion of harvestable ear yield contributed by primary ears increased by 2% for each 10 day delay in sowing ($P<0.01$) (Fig. 3).

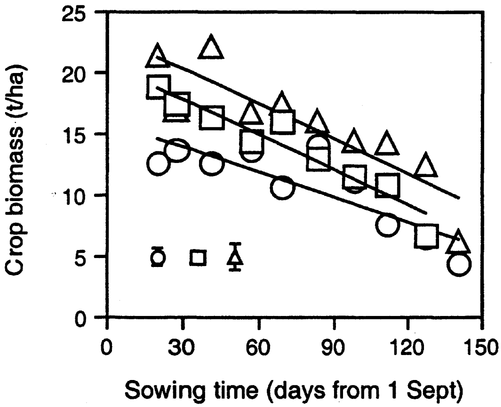

Figure 1. Effect of sowing time on crop biomass of three sweet corn hybrids. ○ Sheba; □ Challenger; △ XP 1029. Bars are RMS errors for each linear fit. Where bars are not visible the error is smaller than the data symbol.

Harvestable cob length declined by an average of only 1 mm for each 10 day delay in sowing ($P<0.01$)(Fig. 4). Consequently, the relationship is of greater statistical than practical significance. Cob length was generally higher in hyb. Sheba than in Challenger or XP1029.

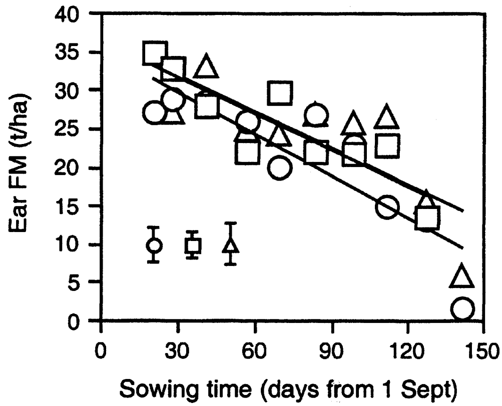

Figure 2. Effect of sowing time on harvestable ear fresh mass of three sweet corn hybrids. Symbols and error bars as in Figure 1.

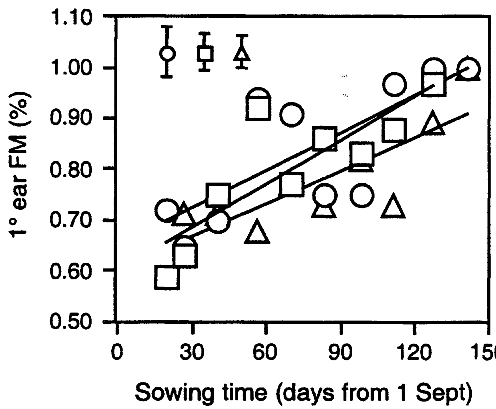

Figure 3. Effect of sowing time on percentage harvestable ear fresh mass from primary ears, for three sweet corn hybrids. Symbols and error bars as in Figure 1.

The proportion of cob length occupied by filled (fully developed) kernels did not respond to sowing time for crops sown from late September through to late November and thereafter it differed somewhat among hybrids (Fig. 5). Hyb. Challenger showed very little response to sowing time whereas late (mid December onwards) sowings significantly reduced cob filling in hyb. Sheba and XP1029.

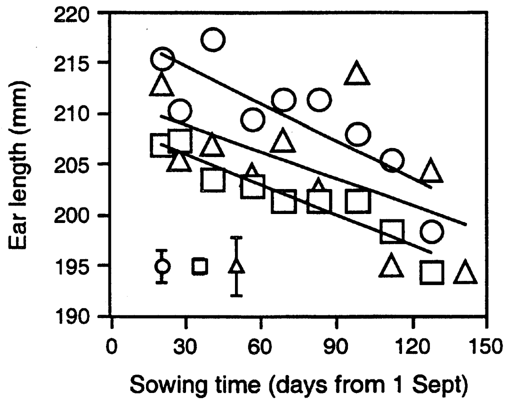

Figure 4. Effect of sowing time on harvestable ear length of three sweet corn hybrids. Symbols and error bars as in Figure 1.

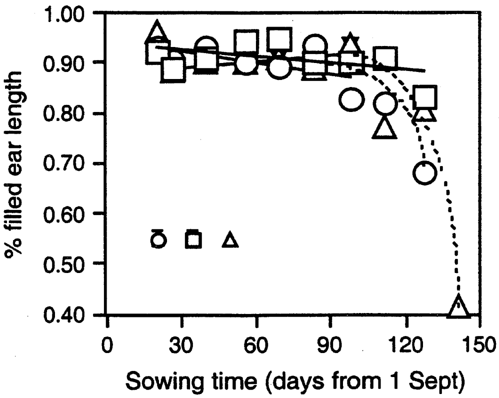

Figure 5. Effect of sowing time on percentage cob fill of harvestable ears, for three sweet corn hybrids. Symbols and error bars as in Figure 1. Hatched lines show departure from simple linear trend.

There was no systematic effect of sowing time on cob diameter of any hybrid for crops sown from late September to late December (Fig. 6). Thereafter, cob diameter declined by 5-10 mm.

There was no significant effect of sowing time on kernel recovery for crops sown from late September to early January (Fig. 7). Very late (late January) sowings

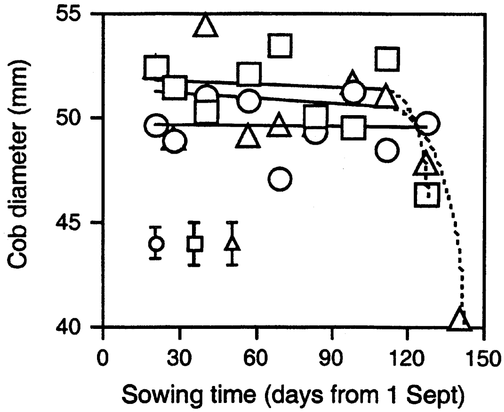

Figure 6. Effect of sowing time on cob diameter of harvestable ears, for three sweet corn hybrids. Symbols, error bars and line as in Figure 5.

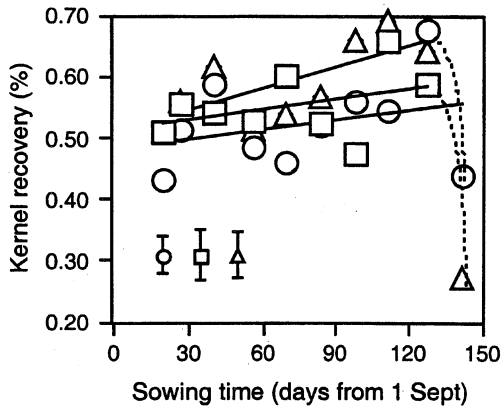

Figure 7. Effect of sowing time on kernel recovery of three sweet corn hybrids. Symbols, error bars and line as in Figure 5.

caused a sharp reduction in kernel recovery of all hybrids.

While there were significant differences among hybrids, there was no consistent or significant effect of sowing time on kernel yellowness (b-value) (Fig. 8). Kernels of hyb. Sheba and Challenger were significantly (P<0.001) more yellow than those of hyb. XP1029.

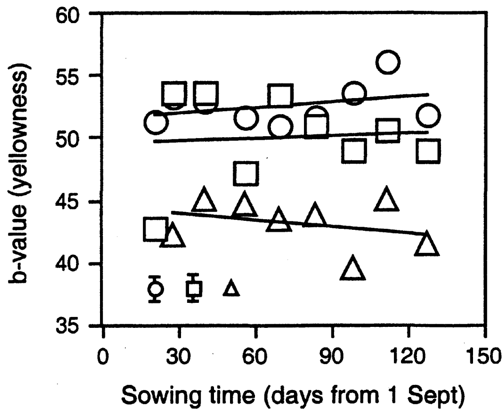

Figure 8. Effect of sowing time on kernel yellowness (b-value) of three sweet corn hybrids. Symbols and error bars as in Figure 1.

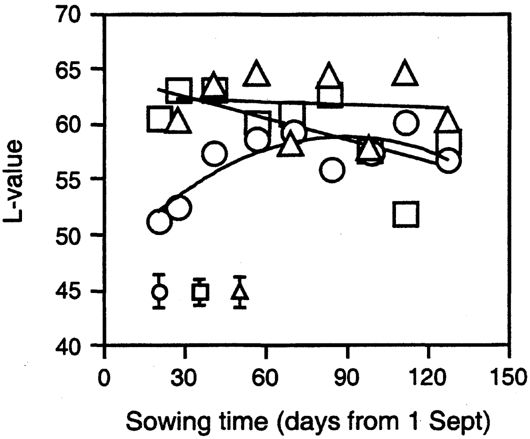

Figure 9. Effect of sowing time on depth of kernel colour (L-value) for three sweet corn hybrids. Symbols and error bars as in Figure 1.

Similarly, the effect of sowing time on depth of kernel colour (L-value) was minor compared with the effect of hybrid (Fig. 9). Sheba was significantly (P<0.001) lighter in colour than XP1029.

For crops sown from late September to late December, kernel toughness declined by *ca* 5 g/mm^2 for each 10-day delay in sowing (Fig. 10). Before or after this period kernel toughness was unpredictable. Hybrid had a more predictable effect on kernel toughness than sowing time, with hyb. Challenger having tougher kernels (P<0.01) than either hyb. Sheba or XP1029.

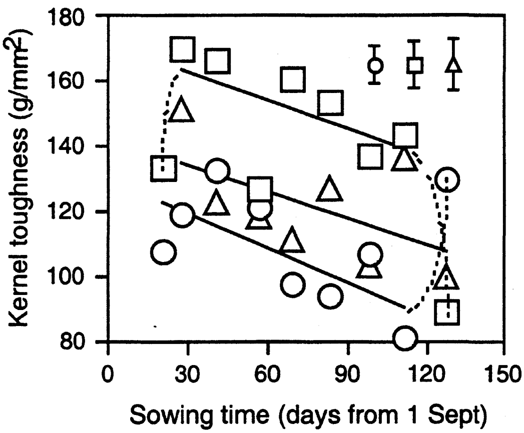

Figure 10. Effect of sowing time on kernel toughness for three sweet corn hybrids. Symbols and error bars as in Figure 1. Hatched lines show departure from simple linear trend.

Discussion

Yield and quality of sweet corn responded differentially to sowing time. Biomass and harvestable ear yield declined as sowing time was delayed, whereas kernel tenderness improved and colour remained relatively stable.

Harvestable ear yield declined with delayed sowing time mainly because of a reduced contribution of secondary ears to yield. The effect of sowing time on primary ears was relatively minor: ear length declined by only *ca* 10 mm and there was virtually no change in cob fill or diameter for sowing times spread over a 4 month period. This strongly suggests that primary ears are the principal recipients of assimilate and that secondary ears receive only that which is left after the primary ears have attained close to their upper size limit. Supporting this supposition is the fact that there was a very strong ($P<0.001$) linear relationship between crop biomass and harvestable ear dry mass for each hybrid (Fig. 11). Partitioning of biomass to harvestable ear yield therefore occurred with equal efficiency at all sowing times, but as assimilate became more scarce because of delayed sowing less was available for secondary ears.

If it is accepted that secondary ears accumulate mass only after primary ears have had their fill of assimilate, there may be important implications for crop management. Primary ears are more even in size than a mix of primary and secondary ears, and are consequently easier to grade and process and to sell as whole cobs (either fresh, frozen or pouched). Given that the assimilate available to early sown crops exceeds the requirement of primary ears, as evidenced by the significant partitioning to secondary ears, it is highly probable that higher than normal plant populations could be employed for early sown crops without any significant negative impact on primary ear size. In fact, the advantage is likely to be two-fold: an increase in the proportion of primary ear mass would most likely be accompanied by an increase in total ear mass, as higher plant populations tend to increase radiation interception, biomass and yield (Stone *et al.* 1998a, 1998b).

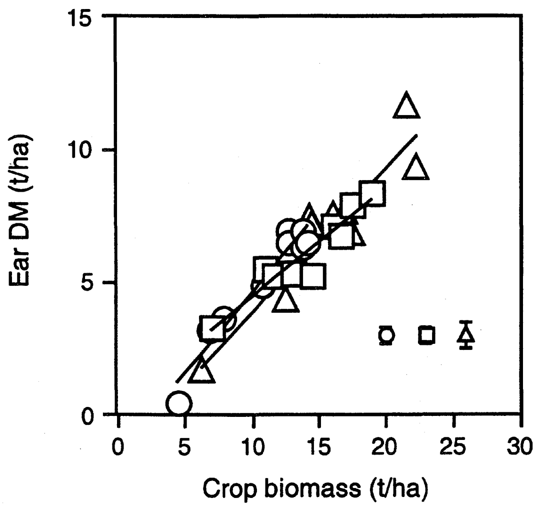

Figure 11. Effect of sowing time on relationship between harvestable ear DM and crop biomass, for three sweet corn hybrids. Symbols and error bars as in Figure 1. Hatched line shows 0.5 harvest index.

In summary, early sowing had the two-fold advantage of increasing harvestable ear yield and the proportion of large primary ears. These advantages could be built upon by planting early sown crops at higher than standard populations.

The effect of sowing time on kernel colour was small compared with the effect of hybrid. Targets for kernel colour (should they exist) are therefore more likely to be met by choosing hybrids with appropriate colour characteristics than by manipulating the crop environment (temperature and radiation).

Kernel toughness was the only component of yield or quality to benefit from a delay in sowing, with kernels becoming more tender in later-sown crops. It should be noted that while there was a significant and predictable effect of sowing time on kernel toughness, there was greater variation available through hybrid choice than through altering the sowing time. Given the yield penalty incurred through delayed sowing, it seems likely that kernel tenderness targets (should they exist) will be better met by careful choice of hybrid than by choice of sowing time. Quality data presented here will be used in subsequent work to provide a basis for comparing genotypic differences in kernel toughness and colour.

Conclusions

Sowing time was a useful tool for optimising harvestable yield of sweet corn but was a relatively ineffective means of manipulating quality, for which hybrid choice exerted a much greater influence.

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