Effect of plant population and Nitrogen fertiliser on yield and quality of super sweet corn

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Abstract

Yield and quality of supersweet corn cv. Challenger are sensitive to changes in plant density and nitrogen nutrition. This study examined the effects of plant population (nine populations ranging from c. 30,000 to 140,000 plants/ha) and nitrogen (N) fertiliser (nil and 250 kg N/ha) on yield and quality. When N fertiliser was added, ear and grain yield increased with the $\log_{10}$ of population, throughout the population range examined. When N was limiting ear and grain yield increased with population up to c. 90,000 plants/ha, then remained unchanged. The limiting effects of -N treatment on yield became more pronounced at high (>90,000 plants/ha) populations. Quality characteristics such as ear size, tip fill and individual grain mass were consistently improved by +N treatment throughout the range 30,000 to 140,000 plants/ha, compared with -N treatment. Ear size, tip fill and individual grain mass declined with population, regardless of N supply. Results are discussed in terms of manipulating population and N supply to attain the optimum balance between yield and quality for a variety of supersweet corn products.

Additional key words: *plant density, ear numbers, grain yield, ear size, tip fill, grain mass*

Introduction

Prediction of sweet corn yield and quality is essential to reliably assess the expected economic benefits of inputs such as irrigation and fertiliser. Mechanistic growth models based on radiation interception are perhaps the most reliable predictors of potential yield, as crop growth is closely related to the amount of radiation intercepted by the crop canopy (Monteith, 1972; Mac *et al.*, 1990). Plant population is a simple management factor which has a large effect on radiation interception. Consequently, to be reliable, a model must be able to account for the effects of population on radiation interception and, hence, growth and yield. Furthermore, for sweet corn product, quality is at least as important as yield. Given that yield and quality are to some extent inversely related (Mack, 1972; Ahmadi *et al.*, 1993) the optimum plant population will involve something of a compromise between these two characters. Identifying that optimum for different products is an important component of any useful management strategy.

An added complication in the yield/quality/population equation is plant nutrition. Through its gross effects on both leaf size (Wolfe *et al.*, 1988) and radiation use efficiency (Sinclair and Machow, 1995) of *Zea mays*, nitrogen (N) nutrition is likely to exert a significant influence on crop growth. Furthermore, N nutrition is likely to affect the balance between plant population and yield and quality.

In this study, we examined the effects of plant population and nitrogen nutrition on radiation interception, yield and quality of super-sweet corn cv. Challenger, with a view to more reliably optimising management of sweet corn for profit.

Materials and Methods

The experiment was performed in a temperate climate at Hastings, New Zealand (39° 28'S, 176° 38' E) where temperature and radiation during the sweet corn growing season average c. 17°C and 20 $MJ/m^2/d$. A site description is given in Reid and Renquist (1997).

On 6 November 1997, duplicate plots of super-sweet corn cv. Challenger were hand planted at nine populations ranging from c. 30,000 to 140,000 plants/ha. Seeds were sown at 5 cm depth, with a row spacing of 70 cm. Within three weeks of sowing, half the plots received 250 kg N/ha (+N) as urea, banded next to rows at 5 cm depth, and half received no N fertiliser (-N). All plots received phosphorus (25 kg P/ha as superphosphate) banded as above, and potassium (25 kg K/ha as KCl) was dissolved in water and applied between rows with a watering can. Treatments were fully randomised. Plots were 9 x 15 m. The site was fertile compared with commercial sweet corn paddocks, with an soil test average of 105 kg available N/ha (method of Keeney & Bremner, 1966), 14 µg/mL Olsen P and 1.1 m.e./100 g K.

Tip appearance, full expansion and complete senescence of each leaf were recorded twice weekly, on five tagged plants per plot. The area of individual leaves was measured destructively on three plants per plot at 48 and 75 days after sowing. Together, these two sets of data were used to calculate the development of green leaf area index (GLAI) on a daily basis. Using the radiation interception formula of de Wit (1965) and an extinction coefficient of 0.4 (Mac *et al.*, 1990), the GLAI was used to calculate the daily radiation interception by the crop canopy.

At maturity (72% grain moisture content), crop biomass and yield were measured from 20 plants, selected randomly from each plot. Yield and quality components were measured on a 10 ear subsample, from which harvestable ears were defined as those longer than 20 cm. Moisture content was determined from a subsample of three plants per plot, dried to a constant mass in a fan forced oven at 75°C.

Statistical analysis was performed using standard linear regression techniques. Differences between regressions were determined using two-tailed paired t-tests.

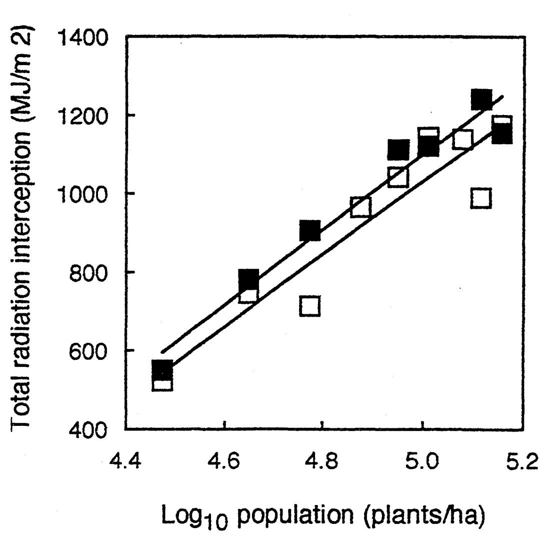

Figure 1. Relationship between (log_{10}) plant population and total radiation interception by super-sweet corn cv. Challenger. Plant population varied from c. 30,000 to 140,000 plants/ha. ■ +N; □ -N.

Results

Radiation interception

Total radiation intercepted by the crop canopy increased linearly with the log_{10} of population for both the +N (R^2 = 0.96; P<0.001) and -N (R^2 = 0.87; P<0.001) treatments (Fig. 1). The response of radiation interception to population was the same for both N treatments, although on average for all populations, the +N treatment intercepted about 75 MJ/m^2 more than the -N treatment (P<0.1).

Biomass

For +N treatments, crop biomass increased linearly with the log_{10} of plant population throughout the entire population range (R^2 = 0.88; P<0.001) (Fig. 2). For -N treatments, crop biomass increased linearly with the log_{10} of plant population in the range 30,000 to 90,000 plants/ha (R^2 = 0.96; P<0.01), but showed no significant response to higher populations. Crop biomass was closely related to total radiation interception, although the relationship was stronger for the +N (R^2 = 0.92; P<0.01) than the -N (R^2 = 0.72; P<0.01) treatments (data not shown).

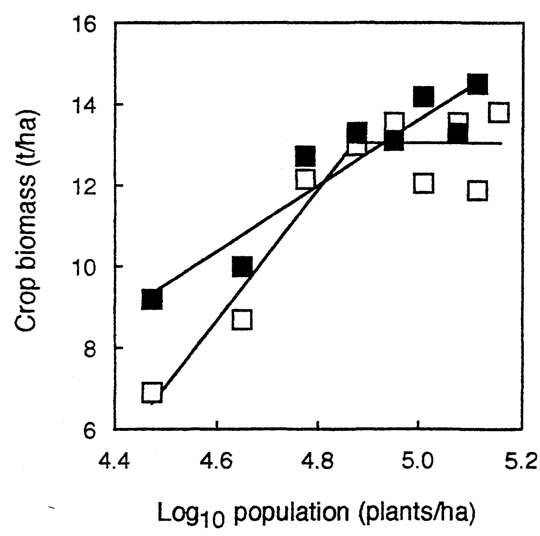

Figure 2. Relationship between (log_{10}) plant population and crop biomass of super-sweet corn cv. Challenger. ■ +N; □ -N.

Ear and grain yield

For +N treatments, harvestable ear fresh mass (FM) increased linearly with the $\log_{10}$ of plant population throughout the population range examined ($R^2 = 0.96$; $P<0.001$) (Fig. 3). By contrast, harvestable ear FM of -N treatments increased with the $\log_{10}$ of plant population only up to c. 90,000 plants/ha ($R^2 = 0.92$; $P<0.01$), and did not respond to further increases in population.

Harvestable grain FM of +N treatments increased linearly with the $\log_{10}$ of plant population ($R^2 = 0.98$; $P<0.001$) (Fig. 4). For -N treatments, harvestable grain FM increased to a maximum at 90,000 plants/ha ($R^2 = 0.95$; $P<0.01$) but thereafter an increased population reduced grain FM by up to 2 t/ha ($R^2 = 0.80$; $P<0.1$).

Quality components

Fresh mass per ear declined linearly with plant population for both +N ($R^2 = 0.94$; $P<0.001$) and -N treatments ($R^2 = 0.88$; $P<0.001$) (Fig. 5). For all populations, addition of N fertiliser increased FM per ear by an average 30 g ($P<0.05$).

Tip fill declined linearly with increased population, regardless of N treatment. The number of unfilled florets per ear increased by c. 1 per 1000 plants/ha throughout the population range examined ($R^2 = 0.84$; $P<0.001$), from a minimum of 20 to a maximum of c. 120 (data not shown). This was equivalent to an unfilled tip length of 0 to 3 cm.

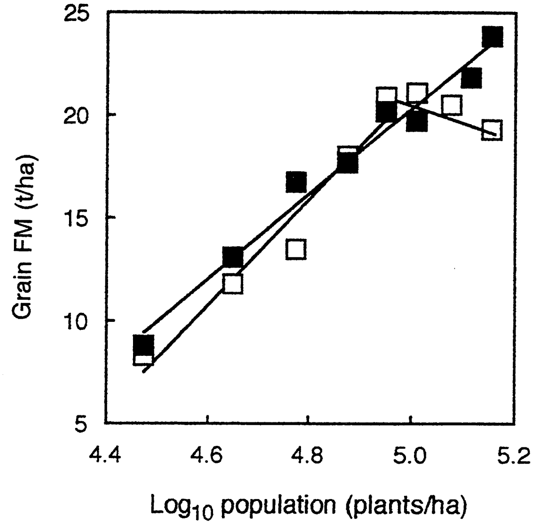

Figure 4. Relationship between ($\log_{10}$) plant population and grain fresh mass (FM) of super-sweet corn cv. Challenger. ■ +N; □ -N.

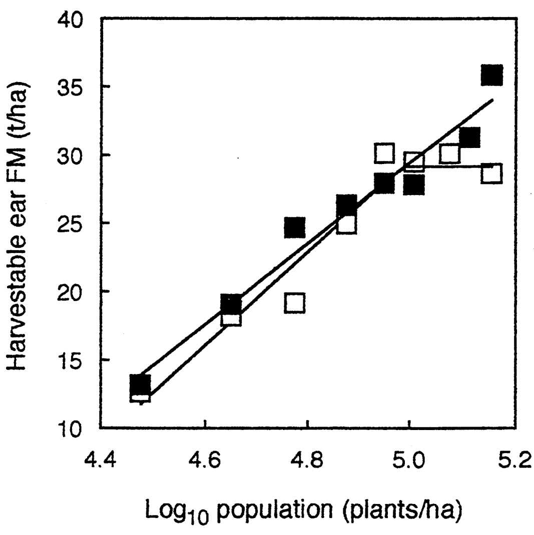

Figure 3. Relationship between ($\log_{10}$) plant population and harvestable ear fresh mass (FM) of super-sweet corn cv. Challenger. ■ +N; □ -N.

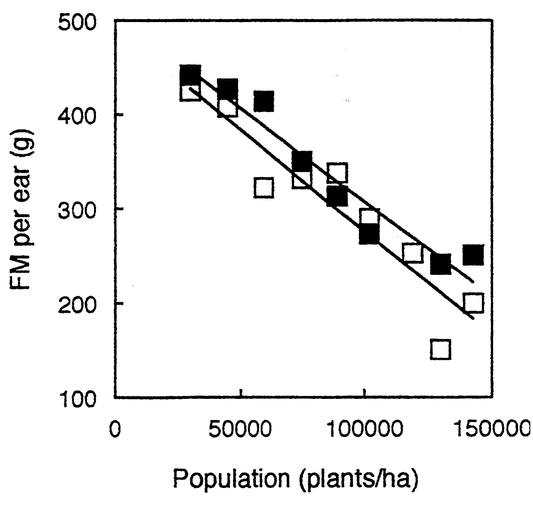

Figure 5. Relationship between plant population and fresh mass (FM) per ear of super-sweet corn cv. Challenger. ■ +N; □ -N.

The fresh mass of individual grains declined curvilinearly with population, for both N treatments, from maximum of c. 400 mg to a minimum of c. 220 mg (R^2 = 0.91; P<0.001) (Fig. 6). Addition of N increased fresh mass of individual grains by an average of 13 mg (P<0.05), across the range of populations examined.

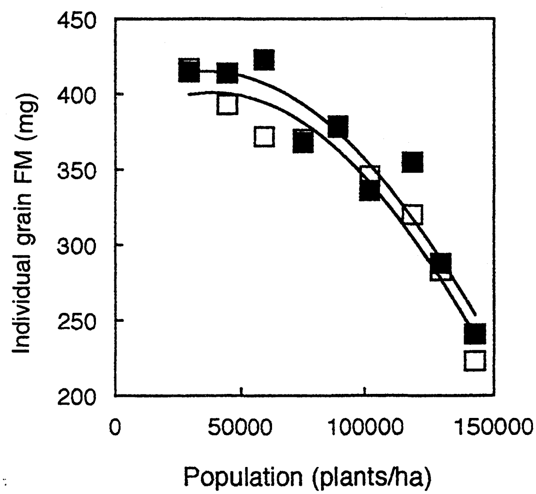

Figure 6. Relationship between plant population and individual grain fresh mass (FM) of super-sweet corn cv. Challenger. ■ +N; □ -N.

Discussion

The yield of super-sweet corn cv. Challenger was related to the total amount of radiation intercepted by the crop canopy. This increased with plant population because of both a reduced time to canopy closure and a greater maximum leaf area index (data not shown).

The addition of N fertiliser tended to increase radiation interception, although at the high levels of soil N in this experiment, the effect was not great. Radiation use efficiency (RUE) was not affected by population when N was adequate, but the biomass plateau attained by -N treatments for populations >90,000 plants/ha is evidence of impaired RUE when high population and inadequate N were combined. This effect on biomass fed through into the fresh mass of both ears and grains, for which there was no significant effect of N fertiliser until population exceeded 90,000 plants/ha.

Given adequate nutrition, the yield of cv. Challenger super-sweet corn should reach a maximum when radiation interception is maximised. This will occur at some population in excess of 140,000 plants/ha, or over twice the currently recommended planting density for cv. Challenger. When nitrogen is limiting, however, the total amount of radiation interception appears to become less important than the ability to convert radiation to biomass. In this instance, inadequate N resulted in a yield plateau at c. 90,000 plants/ha, despite the fact that radiation interception continued to increase up to 140,000 plants/ha.

While biomass and yield tended to increase with plant population, the size of individual yield components decreased with population. The decline of whole ear mass, individual grain mass and tip fill with increased population has important implications for product quality.

The value of shrink-wrapped super-sweet corn is highly dependent on total ear length and tip fill, each of which is highly sensitive to plant population. Consequently, the population optimum for this product is likely to involve a compromise between obtaining the greatest number of ears/ha and acceptable ear dimensions, which coincide with an individual ear mass of c. 400 g. Our data suggest that for a well managed crop of cv. Challenger, this is likely to occur at a population of c. 55,000 plants/ha. For the -N crop, however, the population required to attain acceptable ear dimensions for shrink-wrapped super-sweet corn was c. 42,000 plants/ha. Clearly, the yield of saleable ears will be much higher if N is adequate.

Grain dimensions are an important attribute of frozen and canned corn, with consumers showing a distinct preference for larger grains. The relative insensitivity of grain mass to lower populations suggests that the density at which Challenger is commonly grown could be increased by as much as 10,000 plants/ha, without any significant impact on grain size. This would increase the canning yield by over 2 t/ha (12%), while maintaining product quality. N nutrition did not affect the response of grain size to population, but by increasing individual grain mass, N enhanced this aspect of product quality across the entire range of populations examined.

Conclusions

Nitrogen did not generally limit yield until plant population reached very high levels (about twice those currently recommended). However, because inadequate N reduced sweet corn quality, there were significant benefits of N fertiliser application. The optimum plant population for cv. Challenger super-sweet corn varies with intended end use, and is likely to be higher for canning or freezing than for shrink-wrapping.

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