Optimum plant population for maize silage in Canterbury

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Abstract

Few studies have investigated the optimum plant population for maize silage in the South Island. Most planting recommendations come from studies in the warmer North Island. Growers in the South Island face a different environment and use shorter season hybrids. For these reasons it is likely that optimum plant populations may be higher in Canterbury. This research examined the effect of plant population (65,000 plants ha^{-1} to 190,000 plants ha^{-1}) on maize silage dry matter yield, quality (grain yield) and economic value in a trial on a mid-Canterbury farm. Increasing the population increased DM yield, but there was no clear yield plateau. Plant population had no effect on grain yield. The change in dry matter content during maturation and therefore the projected harvest dates were not affected by plant population. An economic assessment showed there was increased profitability at plant populations as high as 150,000 or 170,000 plants ha^{-1}. This is well beyond currently recommended plant populations.

Additional keywords: sowing rate, maize hybrids, plant density, *Zea mays*

Introduction

Choice of plant population is a key factor in maximising profitability of silage crops. In New Zealand, research on optimum maize population density has generally been focused on grain crops in the North Island. Stone *et al*. (2000) studied maize grain yield at three North Island sites and found a yield plateau at around 120,000 plants ha^{-1}. In a rare study with maize silage crops, Densley *et al*. (2003) identified optimum plant populations of 115,000 to 130,000 plants ha^{-1}.

Modern maize hybrids have been bred with improved tolerance to stresses such as low moisture levels, low night temperatures and improved growth at high sowing rates. These hybrids enable growers to increase sowing rate and yield (Tollenaar and Wu, 1999). As plant population is increased, yield has been reported to increase until a plateau is reached (Cusicanqui and Lauer, 1999). Limitations to yield at high populations are driven by the crop's capacity to intercept solar radiation (Stone *et al*., 1998). The point at which a yield maximum is reached will depend on the agronomic practices used and the growth potential in the target environment (Olson and Sander, 1988).

North and South Island growing environments are very different and therefore hybrid choice is important for ensuring crops develop to maturity. Growers in the South Island plant hybrids with shorter growth duration than in warmer North Island situations. The interactions between physical environment, hybrid and population have not been adequately evaluated. The potential benefits of higher plant populations in more southern latitudes may result from:

(1) Improved light capture. In southern regions a higher plant population may be necessary for short season hybrids to maximise solar radiation interception. Short season hybrids typically yield less as they have a shorter crop duration with fewer and smaller leaves than long season hybrids. Therefore, they intercept less solar radiation.
(2) More efficient canopy growth. Higher plant population minimises the time for crops to reach canopy closure. Cool spring air temperatures in South Island locations mean that leaf area development is delayed, and therefore optimum plant populations may well be higher for southern latitudes.

The aim of this study was to investigate the effect of plant population on maize silage yield, quality and profitability in Canterbury. The proportion of grain in the harvested dry matter (DM) was used as an indicator of silage quality.

Materials and Methods

Site and agronomic management

The trial was sown in a commercial maize crop near Southbridge, mid-Canterbury (43.81 °S, 172.25 °E). The paddock had previously been in perennial ryegrass pasture for six years. The soil was a Tai Tapu silt loam with good fertility (Table 1).

Table 1: Soil test results for samples taken on 23 September 2008.

Depth (mm)	pH	P (ug ml^{-1})	Ca	Mg	K	Na	S (ug g^{-1})	Anaerobic mineralisable N (kg ha^{-1})	Ammonium NH_4 (mg kg^{-1})	Nitrate NO_3/NO_2 (mg kg^{-1})
0-200	6.0	29	10	25	7	11	8	188	2.7	22.5
200-400	6.2	7	6	33	4	14	9	38	0.3	9.4
400-600	-	-	-	-	-	-	-	13	0.2	2.3
600-900	-	-	-	-	-	-	-	6	1.1	0.5
900-1200	-	-	-	-	-	-	-	4	0.3	0.4
1200-1500	-	-	-	-	-	-	-	4	3.5	0.8

The paddock was sprayed with Roundup @ 4 l ha^{-1} on 20 August 2008 and was cultivated using conventional implements between 25 September 2008 and 6 October 2008. The trial was sown on 13 October 2008 using a 16-row commercial maize planter, with 0.76 m between rows. The hybrid used was 38V12, which has a comparative relative maturity (CRM) of 87 (Anonymous, 2008). The trial was a randomised block design with five target plant populations, 75,000, 90,000, 110,000, 130,000 and 150,000 plants ha^{-1} with four replicates. Each plot was one drill width wide and 15 m long. Due to the short plot length and limitations of the drill reaching the targeted sowing rates within 15 m there was some variation between target and achieved plant populations and there was substantial variation among replicates (Figure 1). Therefore, the plant population achieved in individual plots was used in all subsequent analyses and no attempt was made to average populations across treatments.

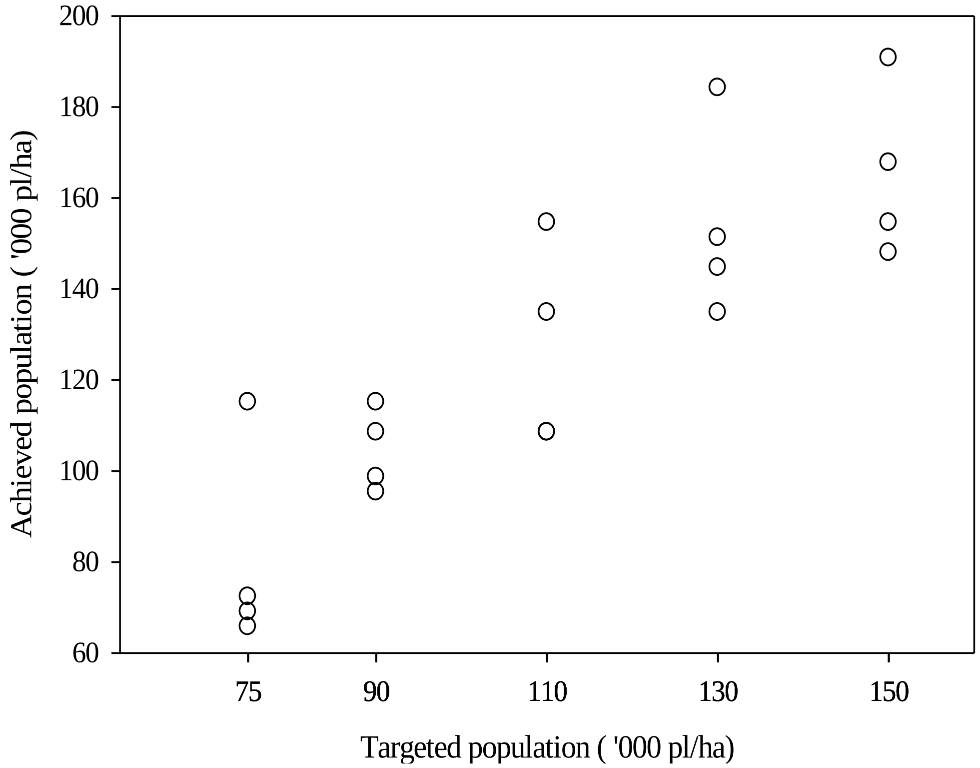

Figure 1: Comparison of target and actual populations. Note for the target population of 110,000 two replicates achieved the same population (108,553 plants ha^{-1}).

Compound fertiliser (12:10:10) was applied at sowing to give 42 kg N ha^{-1}, 35 kg P ha^{-1} and 35 kg K ha^{-1}. The site received two further separate applications of 69 kg N ha^{-1} broadcast as urea. On 20 November 2008 a post-emergence herbicide mixture of Emblem at 2.5 kg ha^{-1} and Atranex WG at 1 kg ha^{-1} in 300 l water ha^{-1} was applied to control wireweed (*Polygonum aviculare* L.), fathen (*Chenopodium album* L.) and cornbind (*Polygonum convolvulus* L.). The paddock was irrigated using a gun irrigator and received a total of 135 mm of irrigation.

Measurements

The trial was harvested on 1 April 2009. Two rows, 2 m in length, were cut from the middle of each plot and plant number and fresh weight recorded. A three plant sub-sample was weighed fresh and then split into leaf, stem and cob components before being dried at 90 °C for 4 days.

Results and Discussion

Population effect on dry matter yield

As plant population increased, crop DM yield increased (Figure 2). Both a linear regression (R^2 = 0.58) and an exponential response (R^2 = 0.62) fitted the data similarly. However, based on an assessment of the residuals and previous results (Cusicanqui and Lauer, 1999), the exponential relationship was chosen. In both analyses, the relationship demonstrated that the biologically optimum plant population was likely to be greater than 120,000 plants ha^{-1}. The results from the final DM yield do not show a clear plateau, which suggests the biologically optimum sowing rate for this environment may have been greater than the highest population tested.

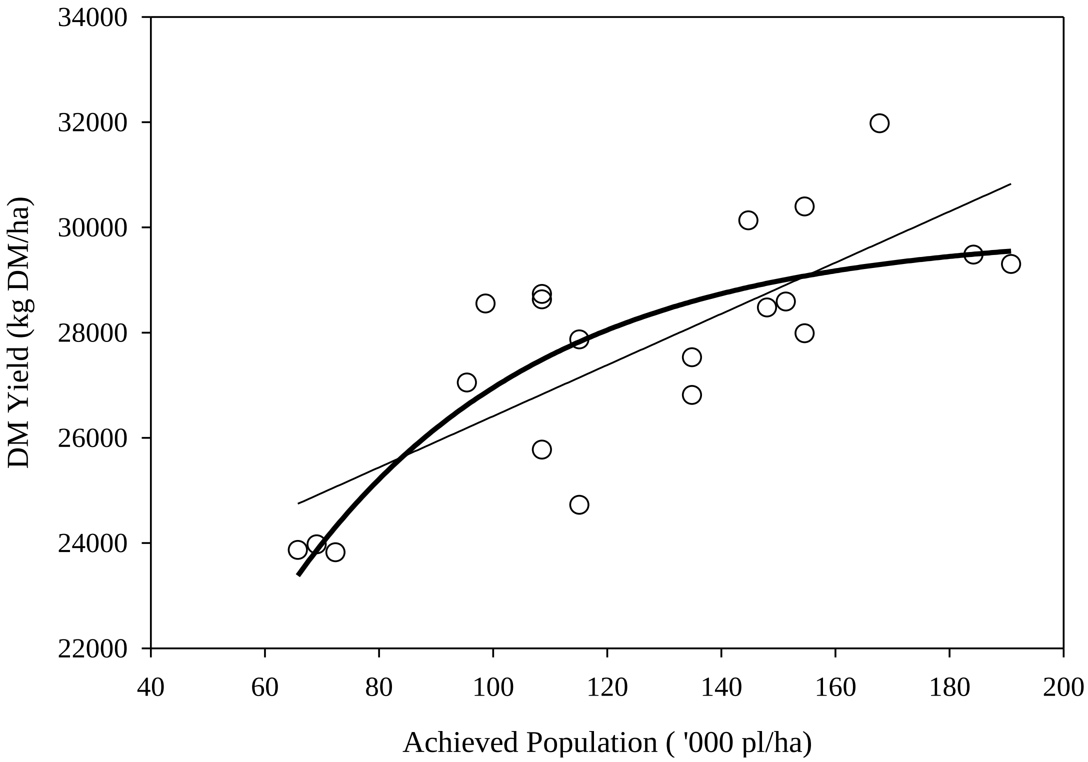

Figure 2: Relationship between maize silage DM yield and plant population. The equation for the linear regression is y = 21546.70 + 0.0486x (R^2 = 0.58). The equation for the exponential response is y = 29911.9 * (1-exp(-2.3131E-005*x)) (R^2 = 0.62).

Population effect on yield per plant

Higher plant population reduced plant size. This decreased exponentially from 362.6 g at 65,789 plants ha^{-1} to 153.6 g at 190,789 plants ha^{-1} (Figure 3). At higher populations smaller plants with narrower stems may be more susceptible to lodging, however, no lodging was observed in this trial. If growers were to adopt higher populations, this risk of lodging should be considered.

While the results for DM yield per plant showed a declining trend with increasing population there was again no clear lower limit within the treatments. The biologically optimum sowing rate for the Canterbury environment was possibly greater than the highest population used in this study.

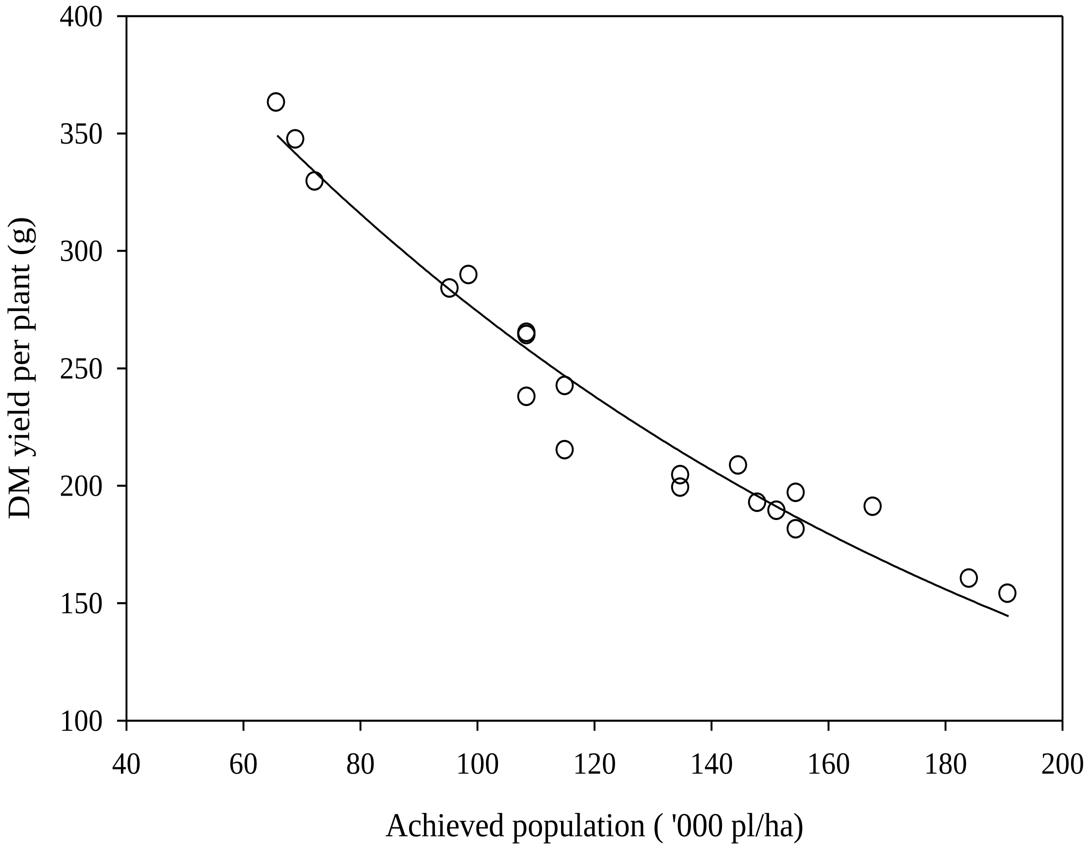

Figure 3: Relationship between DM yield per plant and achieved plant population. The fitted equation is:
Y = 555.4*exp(-7.058E-006*x) (R^2 = 0.95).

Population effect on crop maturity

The similar DM values suggest plants still mature at a similar time regardless of population. If growers increase populations they will still produce good quality silage and the crop will be ready for silage harvest at the same time.

The proportion of grain in the harvested DM did not change with plant population (data not shown). It was consistently 43%. This suggested that the silage quality of the crops was similar. Average crop DM was 33% and this was not affected by plant population (data not shown). This also indicated that crop maturity was not affected.

Economics

Although increasing sowing rates increase yield (Figure 2) they comes at a cost. Compared to other crops, maize seed is relatively expensive and a dense crop may suffer from more disease or water stress, with further costs for agrichemicals and irrigation which were not investigated in this study. It is important to know the point at which the cost of increasing plant population will exceed the increased value of the silage and whether the yield advantage will offset the costs.

To estimate the most economic plant population for the current trial, the exponential regression shown in Figure 2 was used to calculate the increase in silage yield. Seed cost was assumed to be $ 325 bag^{-1} of 80,000 seeds. We also assumed fixed costs (for example paddock preparation (cultivation), fertiliser application, spraying and irrigation) of $2,500. We calculated gross margins for a maize silage price of either $0.20 or $0.30 kg^{-1} of DM.

At $0.20 kg^{-1} silage a maximum profit of $2,687 ha^{-1} came from planting at 150,000 plants ha^{-1}. However, at $0.30 kg^{-1} silage a maximum profit of $5,607 ha^{-1} was achieved by planting 170,000 plants ha^{-1} (Figure 4). Clearly, the economically optimum population varies with the price of silage. However, these sowing rates are substantially higher than the current recommendation of 120,000 plants ha^{-1}. These economically optimum rates must be treated with caution because they are close to the highest population tested in this trial and uncertainty remains as to the overall effect of increasing plant population (Figure 2). However, the results indicate that plant populations could be increased above 120,000 without any loss of profit. Furthermore, although the hybrid used was short season (CRM = 87), even shorter season hybrids are available in New Zealand (e.g. 39G12 CRM = 78; Anonymous, 2008) and it may be possible to produce acceptable returns from plant populations exceeding 150,000 plants ha^{-1}.

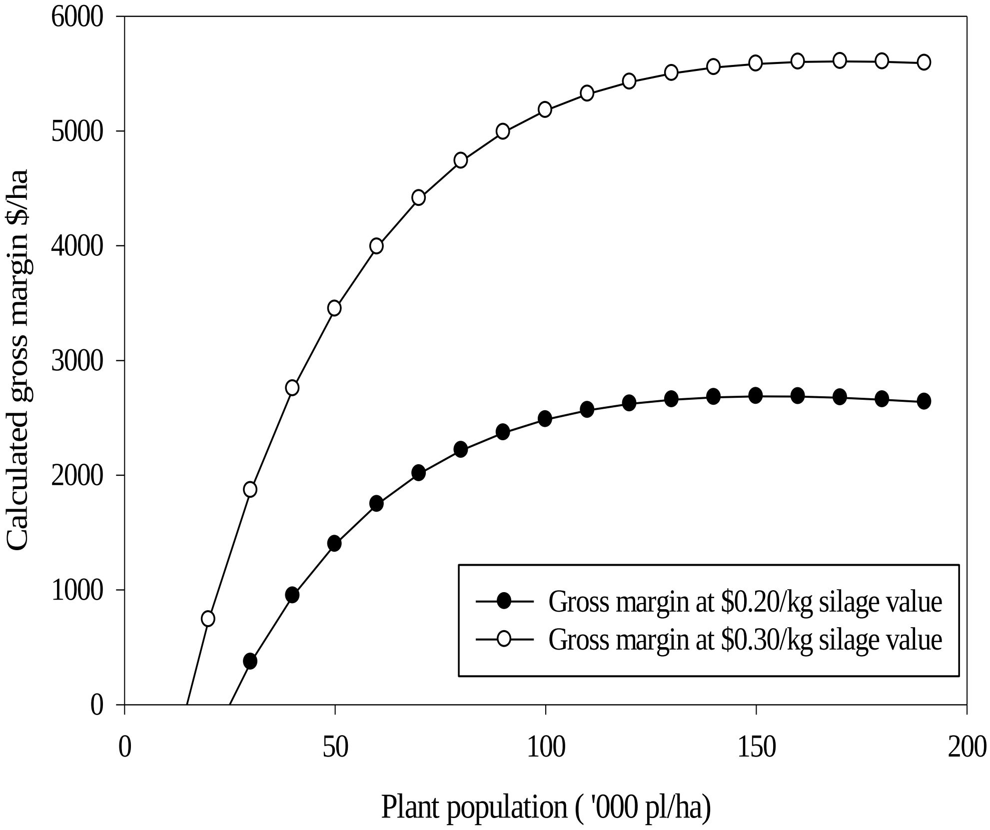

Figure 4: Effect of plant population on gross margins assuming values of maize silage of \$0.20 kg^{-1} and \$0.30 kg^{-1}.

Conclusions

This study showed that populations for maize silage crops in Canterbury could be raised well above current recommendations and still be profitable. At the plant populations tested, yield did not plateau so the biologically optimum sowing rate for the South Island may exceed those used in this study.

Increasing plant population also increased maize silage yield with no clear upper limit. At high populations plant size decreased significantly and there was a potential detrimental effect on quality. However, even at the highest plant populations there was little effect on dry matter development i.e. no effect on harvest timing.

Moreover, harvest index did not differ among plant populations and therefore the quality of the maize was not affected.

Peak gross margins were achieved in the range of 150,000 to 170,000 plants ha^{-1}, with a slow decline in profitability at high populations cause by the additional seed costs out weighing the yield increase. There was little reason to recommend sowing rates beyond 150,000 plants ha^{-1}. However, further study is required to confirm these results.

Acknowledgements

Thanks to Tim Ridgen who hosted the trial on his property. Also thanks to Randal Hanrahan for sowing the trial and the Foundation for Arable Research for funding the trial.

References

Anonymous 2008. Pioneer® Brand Forages. Genetic Technologies Ltd, Auckland. 37 pp.

Cusicanqui, J.A. and Lauer, J.G. 1999. Plant density and hybrid influence on corn forage yield and quality. *Agronomy Journal* 91: 911-915.

Densley, R.J., Brenton-Rule, R.J., Austin, G.M., Densley, D.W. and Tsimba, R. 2003. The effect of increasing plant population on maize silage yield and quality. *Proceedings of the New Zealand Grassland Association* 65: 117–121.

Olson, R.A. and Sander, D.H. 1988. Corn production. pp. 639-686. *In*: Corn and corn improvement. Agronomy Monograph No. 18. Eds Sprague, G.S. and Dudley, J.W. ASA, CSSA, SSSA, Madison, Wisconsin.

Stone, P.J., Sorensen, I.B. and Wilson, D.R. 1998. Radiation interception accounts for the effects of plant population on maize yield. *Proceedings Agronomy Society of New Zealand* 28: 9-10.

Stone, P., Pearson, A., Sorensen, I. and Rogers, B. 2000. Effect of row spacing and plant population on maize yield and quality. *Agronomy New Zealand* 30: 67-75.

Tollenaar, W. and Wu, J. 1999. Yield improvement in temperate maize is attributable to greater stress tolerance. *Crop Science* 39: 1597-1604.