

New Zealand Society of Animal Production online archive

This paper is from the New Zealand Society for Animal Production online archive. NZSAP holds a regular annual conference in June or July each year for the presentation of technical and applied topics in animal production. NZSAP plays an important role as a forum fostering research in all areas of animal production including production systems, nutrition, meat science, animal welfare, wool science, animal breeding and genetics.

An invitation is extended to all those involved in the field of animal production to apply for membership of the New Zealand Society of Animal Production at our website www.nzsap.org.nz

[View All Proceedings](#)

[Next Conference](#)

[Join NZSAP](#)

The New Zealand Society of Animal Production in publishing the conference proceedings is engaged in disseminating information, not rendering professional advice or services. The views expressed herein do not necessarily represent the views of the New Zealand Society of Animal Production and the New Zealand Society of Animal Production expressly disclaims any form of liability with respect to anything done or omitted to be done in reliance upon the contents of these proceedings.

This work is licensed under a [Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License](http://creativecommons.org/licenses/by-nc-nd/4.0/).



You are free to:

Share— copy and redistribute the material in any medium or format

Under the following terms:

Attribution — You must give [appropriate credit](#), provide a link to the license, and [indicate if changes were made](#). You may do so in any reasonable manner, but not in any way that suggests the licensor endorses you or your use.

NonCommercial — You may not use the material for [commercial purposes](#).

NoDerivatives — If you [remix, transform, or build upon](#) the material, you may not distribute the modified material.

<http://creativecommons.org.nz/licences/licences-explained/>

Advances in maize silage genetics and crop management and the impact on the NZ dairy industry

R. J. DENSLEY, I. D. WILLIAMS, D.B. MILLER, D. W. DENSLEY, D.A. SAPIENZA¹

Genetic Technologies Ltd, PO Box 105-303, Auckland, New Zealand

ABSTRACT

Significant lifts in profitability have been achieved by New Zealand dairy farmers through the inclusion of increasing amounts of maize silage into a pasture based system. Most of this maize is grown off the dairy unit on farmer owned or leased runoff blocks or by contract growers. While there is still significant scope to improve dairy farm productivity by increasing maize silage input levels, there is considerable opportunity to also improve dairy farm productivity by reducing feed costs through improving maize silage yields, increasing milk output by lifting maize silage nutritional quality and improving agronomic stability of maize silage offering higher yields over a wider environmental range. Traditional plant breeding, genetic engineering and advances in agronomic management all have the potential to impact production potential and profitability of maize silage in New Zealand dairy farm systems.

Keywords: Maize silage; maize genetics, maize agronomy.

INTRODUCTION

New Zealand dairy farmers are using maize silage as a cost effective energy source to supplement pasture. Maize silage usage has increased over the past decade. Livestock Improvement Profitwatch data for the 1999-2000 season indicated that 47% of Waikato dairy farmers used maize silage. Since the 1997-98 season, maize silage usage had increased from an average rate of 193 kgDM/cow to 339 kgDM/cow (Kolver *et al.*, 2001).

Maize is primarily used to support an increase in cow milking days per ha through a combination of allowing an increase in lactation length and an increase in stocking rate to drive production and improved profitability. An initial look at the Dexcel Profitwatch data for the 2002-03 season of those farms that bought maize silage onto the home dairy unit relative to those that bought in no maize silage supported the merits of this approach. The data showed that dairy farmers feeding more than 2t DM/ha maize silage had a longer lactation length, higher milksolids per cow and per ha, higher cows milked per labour unit, higher EFS per ha and greater return on capital than non-maize silage users.

Annual productivity gains for New Zealand dairy farmers are likely to come from the inclusion of increasing amounts of energy supplements into the traditional pasture based system. For many, maize silage is the only cost effective supplement that can be accessed in large volumes. Future developments in yield potential, agronomic stability and nutritional qualities will all be important in maintaining our low cost production base.

Given that maize is a hybrid crop (an annual) and is the world's largest crop on a tonnage basis, companies and universities have established significant research

programmes that have targeted additional yield and improved agronomic stability as well as quality traits. Pioneer Hi-Bred International alone spends more than \$NZ617 million per annum on maize hybrid research. The results of this research development effort are significant. During the last 40 years New Zealand maize silage yields have almost trebled (Deane, 1999). Maize hybrid breeding efforts will combine with improved crop management to lift maize silage yields and quality into the future.

Current New Zealand research is focused on improving crop management practises to lift yield and quality as well as building pasture and maize silage based dairy farm systems that are profitable and sustainable. While genetic advances through traditional plant breeding methods continue to lift New Zealand maize silage yield and quality, the current market and regulatory environment precludes the use of genetically modified products. This may change in the future.

The results of the combined global maize research and development will deliver on-farm productivity gains to the New Zealand dairy industry in the next 10 years by:

1. Reducing feed costs through improving maize silage yields
2. Increasing milk output by increasing maize silage nutritional quality
3. Improving agronomic stability of maize silage giving more stable yields across a wider environmental range.

TABLE 1: Comparison of dairy farm systems with or without maize silage (Profitwatch Data 2002-03 season).

	Amount of maize silage purchased in		
	0 kgDM	> 50t DM total	> 2t DM/ha
Number of farms in sample	128	45	8
Maize silage per cow (kgDM)	0	541	888
Maize silage per hectare (kgDM)	0	1575	2949
Total bought in supplements fed per ha (kgDM)	2143	4218	6633
Milksolids/cow (kgMS)	328	353	384
Milksolids / ha (kgMS)	861	1029	1276
Stocking rate (cows/ha)	2.62	2.91	3.32
Lactation length (days)	256	268	274
Cows/labour unit	110	133	139
EFS (\$/ha)	858	1014	1377
Return on capital excluding appreciation (%)	3.8	4.0	4.5

INCREASING MAIZE SILAGE YIELDS

Since many of the costs associated with maize silage are fixed, small increases in maize silage yield will significantly impact the cost per unit of drymatter and therefore the profitability of dairy farm systems using maize silage.

Stress tolerance

Over the past century, maize yield gains have resulted from improved hybrid genetics and better agronomic practises such as improved soil fertility and weed control. Among these factors, genetic improvement of maize hybrids for superior stress tolerance has likely contributed the most to increased yields. A key result of enhanced stress tolerance is the adoption of higher planting populations (Paszkiwicz & Butzen, 2001a). In a study conducted in Wisconsin, USA during the 1997-98 season, maize hybrids that were commercially released during the period 1900 to 1997 were planted side by side at three locations and yield and quality characteristics were compared. Since 1930 maize silage whole plant drymatter yield has increased at the rate of 128 to 164 kg DM/ha/year. Since 1930 whole plant, stover and cob yields have increased 1.4, 0.7 and 2.4% per year respectively (Lauer *et al.*, 2001).

Biological potential

The biological maximum for maize grain yield was calculated to be 31.5 t/ha (Tollenaar, 1985). This translates to a maize silage yield of approximately 56.7 t DM/ha and is equivalent to the actual yield achieved by Francis Childs, winner of the 2002 USA National Corn Growers Association Contest (Zinkland, 2002). Currently, average New Zealand maize silage yields range between 20-25 t DM/ha (Densley *et al.*, 2001).

Top crops are yielding over 33 t DM/ha. While breeders are continuing to make advances in the yield potential of new hybrids, NZ silage growers have scope to improve crop management practises to enable them to realise the yield potential of the maize genetics currently available.

Planting population

Currently most NZ maize silage growers use planting populations in the range 100 000 to 110 000 plants/ha. A recent study examined the effect of a range of established plant populations (85 000, 100 000, 115 000, 130 000 and 145 000 plants/ha) on the yield and quality of 12 Pioneer® brand maize silage hybrids grown at 13 New Zealand locations over two seasons. As plant population increased, maize silage drymatter yield increased significantly ($P < 0.01$) from 18.66 to 20.52 t DM/ha (Year 1) and from 22.10 to 23.69 t DM/ha (Year 2). While crude protein decreased slightly at the highest populations (145 00 plants/ha) there was no significant effect on any other nutritional parameters (Densley *et al.*, 2003).

The standard maize row width in New Zealand is 76.2cm (30"). Narrow row maize is planted in 38.1 (15") to 50.8cm (20") rows. Research conducted by Pioneer Hi-Bred International in the USA showed that decreasing row width resulted in an average yield increase of 2.6%. Higher yield increases were achieved in the coolest region (5.5%) than in the warmest region (-2.9%) (Paszkiwicz & Butzen, 2001b). A limited amount of New Zealand research suggests that narrow rows may have some promise especially in cooler regions where spring maize growth is slow. Under these conditions planting in narrow rows allows the crop to reach row cover more quickly giving better weed control. Narrow rows allow greater sunlight capture and these factors may combine to improve dry matter

production. Further research is needed to assess the benefits versus the costs of narrow row systems.

Crop inputs

In the future, yield increases will be achieved as the industry gains an understanding of the factors affecting maize plant nutrient uptake. A holistic approach to maize nutrient requirements may involve using a detailed analysis of the soil nutrient status and biological activity levels to develop a soil management and associated fertiliser programme. Areas of current research include “pop-up fertilisers” which are seed-friendly “designer” liquid fertilisers. These “pop-up” fertilisers are applied close to, but not in contact with, the seed at planting time. Placing specific fertilisers at depth to encourage greater and deeper root growth are also being investigated. Work is also being undertaken to understand and measure the effect of beneficial soil bacteria and fungi on maize root development and subsequent yield.

Methods of cultivation are evolving which minimise the effects of soil compaction and maintain or improve soil organic matter levels. This will assist in the creation of a soil environment that encourages greater root development.

Currently maize crop inputs (e.g. planting population, herbicide type and rate and fertiliser type and rate) are determined using average paddock information. Within a paddock there can be significant variation in soil type, fertility, soil moisture holding ability and weed pressure. Precision Farming techniques are enabling growers to supply the actual needs of individual plants by mapping how a range of factors vary across a field using the global positioning system (GPS). In the future, Precision Farming will allow growers to optimise the fertiliser, herbicide and planting population inputs at any given point within a field, increasing maize silage yield and profitably.

Future gains

For a 22 t DM/ha maize crop with total costs (growing to feeding) of \$3340/ha, lifting maize silage yield by 1 tDM/ha decreases maize silage cost by 0.7 c/kg DM. At a milk response of 100 g MS/kgDM maize silage fed and a milk payout of \$3.50 /kgMS this results in increased profit of \$350/ha of maize silage grown. If maize silage yield was increased by 5 t DM/ha, drymatter cost would decrease by 2.8 c /kgDM and profit would lift by \$1750/ha. It is realistic to expect that this level of yield increase could be achieved within a decade.

INCREASING MAIZE SILAGE NUTRITIONAL QUALITY

Variation in nutritional quality

Significant variation in New Zealand maize silage nutritional quality exists as a result of a combination of genetic, environmental and crop management factors. A recent analysis of a large New Zealand database (n=1611) of maize hybrid nutritive characteristics

showed that differences in nutritive quality accounted for \$34 extra milk income per tonne of maize silage DM, whereas the differences in hybrid yield had a much larger impact on milk income (\$8672/ha maize grown). Modelling through the Cornell Net Carbohydrate and Protein model showed that the supply of energy from maize silage was the key nutritional component affecting milk production (Kolver *et al.*, 2003)

The nutritional traits of maize silage can be readily modified by altering the genes of the plants, either through traditional selection processes or via genetic modification techniques. The energy content of maize silage hybrids can be lifted by increasing starch content and by increasing NDF digestibility.

Starch content

Maize grain contains around 70% starch. Maize silage energy can be most easily lifted by grain content because grain contributes 80% more energy than stover (leaf and stem) on a wet weight basis. Since 1930 cob yields have increased 2.4% per year (Lauer *et al.*, 2001) and Pioneer Hi-Bred International maize breeders are confident that grain yields will continue to rise over the next decade. This will have a large positive impact on the energy levels of maize silage.

Current hybrids vary in starch content due to dilution (as influenced by environmental and genetic factors) and in starch type due to genetic alterations obtained by traditional selection procedures. Starch can be distinguished by chemical type – amylase and amylopectin and by packing density within the corn kernel – floury (soft) and vitreous (hard). The proportion of each starch varies genetically whereas vitreousness varies with genetic and environmental conditions and kernel maturity (Owens, 2002). More research is required to allow us to understand the factors that influence the site, rate and extent of starch digestion within maize silage and its impact on milk production.

Digestibility

Brown mid rib (BMR) is a naturally occurring mutant in corn. BMR corn silage hybrids contain less indigestible fibre, particularly lignin and have more digestible stover than typical hybrids. Acid detergent fibre (ADF) and neutral detergent fibre (NDF) are typically 3% and 2% lower respectively for brown mid-rib hybrids (Lauer & Coors, 1997). Brown mid-rib corn silage gives increased drymatter intakes (Qiu *et al.*, 2000) and as a consequence, higher milk production has been observed in some studies. On the negative side, brown-mid rib hybrids tend to have significantly lower yields, poor standability and poor early season vigour (Lauer & Coors, 1997). In the future, it may be possible for breeders to increase fibre digestibility through genetic manipulation.

Recently Sapienza *et al.* (2004) used cosuppression of a stalk-preferred 4-coumarate: CoA ligase (4CL) gene from maize to produce a transgenic line with sufficient reduction in lignin to increase digestibility without decreasing stalk strength. Internode samples of these

plants showed a 22, 28 and 51% reduction respectively of NDF, ADF and lignin. The transgenic versions of the plants had higher digestibility without compromising stalk strength.

Crop management

From a management perspective, maize silage quality can be altered through crop management practises including time of harvest, cutting height and crop processing. Maize whole plant digestibility may not change very much during the “normal” harvest window for a silage field (30 to 38% whole-plant dry matter) but the relative contribution of ear to the digestible drymatter does change. Usually the percentage ear increases as the kernels fill with starch. Stover digestibility is usually highest at flowering and decreases as the plant matures depending upon plant genetics, the response to the rowing conditions and the association of starch and fibre during ruminal fermentation. The decrease in stover digestibility is independent of its drymatter content until the stover begins to change colour from green to brown. When this colour change appears, the rate of decrease in stover digestibility can increase – the stover becomes less digestible in a shorter time (Sapienza, 2000).

A myriad of fermented maize products can be made from the maize plant. For maximum drymatter yield the whole plant may be harvested a few centimetres above the ground as standard maize silage. At the other extreme, for maximum quality just the grain may be harvested at 28-32% moisture and ensiled. High-cut maize silage will offer the opportunity to lift the level of energy density within the rations of high performing dairy cows. Raising the cutter bar from 10 cm to 51 cm decreased maize silage yield by 10.7% but increased digestibility and net energy for lactation (NE_L) by 1.5% and 4.6%, respectively (Curran & Posch, 2000).

In New Zealand, most of the maize silage is harvested using a forage harvester equipped with a plant processor. This device rolls the chopped particles and thereby disrupts the pericarp of the kernel and exposing more of the starchy endosperm to the cow's digestive process. A plant processor also disrupts the epidermis of the stalk thereby exposing more of the digestible portions of the stalk to the cow's digestive process. Research has shown that plant processing can increase the milk yield from maize silage (Shaver, 1999). Differences in the chop length of maize silage can also affect feed digestibility by dairy cows (Kuehn *et al.*, 1997). In the future, maize silage nutritional gains may be made by altering plant processing and chop length settings on a crop by crop basis.

Inoculants

Bacterial silage inoculants improve the speed and quality of silage fermentation reducing drymatter losses and improving drymatter and fibre digestibility and milk production. In a trial conducted at Washington State University, cows fed maize silage inoculated with Pioneer® brand 1132 had higher milk yields ($P < 0.05$)

than those fed untreated maize silage (Harrison, 1999). Ongoing inoculant research will continue to identify superior strains producing maize silages that have lower fermentation losses, higher feed value and better aerobic stability at feed-out time.

Future gains

In the future maize silage quality will become increasingly important for farmers buying in maize silage on a c/kgDM basis and for maize silage users who are feeding high maize silage rates and/or targeting higher per cow performance.

IMPROVING AGRONOMIC STABILITY OF MAIZE SILAGE

Cold tolerance

Currently maize silage is widely grown from South Canterbury, northwards. In the most southern regions of the country (and at altitude in more northern regions), maize silage adoption is limited due largely to the risk of damage to crops by out-of-season frosts. Researchers at Iowa State University have discovered a way to increase the frost resistance of maize by incorporating a tobacco gene that activates the maize plants natural defence systems against cold temperatures, resulting in an improvement of 2°C in the freezing tolerance of the transgenic maize compared to traditional hybrids (Shou *et al.*, 2004). While the results of this research are very preliminary in that the evaluation was done on seedlings under controlled laboratory conditions, this technology shows promise and in the future, could allow maize to be reliably grown in cool dairy regions (e.g. Southland).

Maize crops mature according to the accumulation of heat units. Longer comparative relative maturity (CRM) hybrids have higher drymatter yield potential but require more heat to reach harvest maturity than shorter CRM hybrids. In maize-under-plastic systems, the maize seed is planted and a thin layer of plastic is mechanically applied over the planted rows. The maize plant grows under the plastic for 5-7 weeks. By the end of this period the combination of the biodegrading plastic and the strengthening maize plant results in the maize plant growing through the plastic. Growing maize silage crops under plastic offers growers in cooler regions the opportunity to achieve higher crop yields (Keane *et al.*, 2003) by providing both frost protection and increased heat in the early stages.

Herbicide resistance

By incorporating genes encoded for enzymes that degrade specific herbicides, hybrids have been developed that are resistant to specific herbicides (e.g. glyphosate or Round-up™ resistance; glufosinate ammonium or Liberty™ resistance). This resistance allows producers to apply specific herbicides to control diverse types of weeds without harming the growing maize plant. While top growers consistently achieve good weed control using conventional hybrids and the wide range of herbicides currently available for use in

maize silage crops in New Zealand, herbicide resistant hybrids may be useful under high weed pressure or in situations where it is difficult to ensure timely herbicide application.

CONCLUSION

The use of maize silage on dairy farms is likely to increase during the next decade as a combination of genetic and crop management practises improve its profitability. Higher profitability will be driven by increasing drymatter yields and therefore reduced feed costs, and improved nutritional quality resulting in higher milk responses per kgDM fed. Genetic advances such as cold tolerance and herbicide resistance combined with management practises (e.g. maize silage under plastic) have the potential to increase the range of environments where maize silage can be profitably grown.

REFERENCES

- Curran, B.; Posch, J. 2000. Agronomic management of silage for yield and quality (cutting height). *Pioneer Crop Insights Vol.10 No.2*. Pioneer Hi-Bred International Inc., Johnston, Iowa.
- Deane, T. 1999. The profitable use of supplementary feeds in pasture based dairy farm systems. *Proceedings of the Ruakura Farmers' Conference 51*: 64-77.
- Densley, R. J.; Miller, D. B.; Kolver, E.S. 2001. Breaking the feed barrier using maize silage. *Proceedings of the New Zealand Grassland Association 63*: 289-293.
- Densley, R.J.; Brenton-Rule, R.J.; Austin, G.M.; Densley, D.W.; Tsimba, R. 2003. The effect of increasing plant population on maize silage yield and quality. *Proceedings of the New Zealand Grassland Association 65*: 117-122.
- Harrison, J. 1999. Effect of Pioneer® brand 1132 corn silage inoculant on the performance of lactating dairy cows fed whole plant corn silage during early lactation. *Pioneer Nutritional Insights*. pp 1-5.
- Keane, G.P.; Kelly, J.; Lordan, S.; Kelly, K. 2003. Agronomic factors affecting the yield and quality of forage maize in Ireland: effect of plastic film system and seeding rate. *Grass & forage science 58*: 362-371.
- Kolver E.S.; Roche J.R.; Miller D.; Densley R. 2001. Maize silage for dairy cows. *Proceedings of the New Zealand Grassland Association 63*: 195-201.
- Kolver, E.S.; Densley, R.; Miller, D.; Williams, I. Sapienza, D.A. 2003. Ranking maize hybrids for silage quality and milk production in pasture-based dairying. *Proceedings of the New Zealand Society of Animal Production 63*: 101-106.
- Kuehn, C.S.; Linn, J.G.; Jung, H.G. 1997. Effect of corn silage chop length on intake, milk production, and rumen function in lactating dairy cows. *1997 Research Summaries*. US Dairy Forage Research Centre, City, State. Pp 83-84.
- Lauer, J. G.; Coors, J.G. 1997. Brown Midrib Corn. *Wisconsin Crop Manager 4 (3)*: 16-18
- Lauer, J. G.; Coors, J.G.; Flannery P.J. 2001. Forage yield and quality of corn cultivars developed in different eras. *Crop science 41*: 1449-1455.
- Owens, F. 2002. Developing new specialty grains for ruminants. *Proceedings of the Florida Ruminant Symposium 13*: 48 -70.
- Paszkiewicz, S.; Butzen, S. 2001a. Corn hybrid responses to plant population. *Pioneer Crop Insights Volume 11*. No 6. Pioneer Hi-Bred International Inc., Johnston, Iowa.
- Paszkiewicz, S.; Butzen, S. 2001b. Narrow width influence on corn yield. *Pioneer Crop Insights Volume 11*. No 5. Pioneer Hi-Bred International Inc., Johnston, Iowa.
- Qui, X.; Eastridge, M.L; Wang, Z. 2003. Effects of corn silage hybrid and dietary concentration of forage NDF on digestibility and performance by dairy cows. *Journal of dairy science 86*: 367 -3674.
- Sapienza, D.A. 2000. Corn Silage: Measuring Nutritive Value with Advancing Maturity. Pre-Conference Symposium, Tri-State Nutrition Conference, Fort Wayne, Indiana.
- Sapienza, D.A.; Vermerris, W. Venhaus, C.A; Dhugga, K.S.; Barker, T.C.; Whitaker, D.; Mullen, J.; Tomes, D.; Helentjaris, T.; Sivansankar, S. 2004. Cosuppression of 4-coumarate: Coenzyme A ligase in maize reduces lignin and increases digestibility without compromising stalk strength. *Nature* (In Press).
- Shaver, R. 1999. Impact of crop processing on corn silage utilization by dairy cattle. Pp. 1-6. <http://www.uwex.edu/ces/forage/wfc/SHAVER1.html>
- Shou, H.; Boddallo, R.; Fan, J.; Yeakley, J.M.; Bibikova, M.; Sheen, J. Wang, K. 2004. Expression of an active tobacco mitogen-activated protein kinase enhances freezing tolerance in transgenic maize. *Proceedings National Academy of Science USA 101*: 3298-3303.
- Tollenaar, M. 1985. What is the current upper limit of corn productivity? *Proceedings of the Conference on Physiology, Biochemistry and Chemistry Associated with Maximum Yield Corn*. Foundation for Agronomic Research and Potash Phosphate Institute, St Louis, Missouri.
- Zinkand, D. 2002. Childs keeps his crown. *Iowa Farmer Today*, December 28th, Pp. 20.