National and regional maize grain and silage strip trial yields

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Abstract

Maize (*Zea mays*) grain yield in New Zealand has increased linearly, on average by 104 kg/ha/year (R^2=0.51) while maize silage yield has increased linearly on average by 166 kg DM/ha/year (R^2=0.47), based on strip trial data (1991-2015 for grain, and 1996-2015 for silage). Over the same periods, grain yields (based on 14% moisture content) have increased on average in the lower North Island (LNI) by 175 kg/ha/year (R^2=0.45) while average silage yields have increased in the Waikato by 212 kg DM/ha/year (R^2=0.48), in the LNI by 177 kg DM/ha/year (R^2=0.31) and the South Island by 155 kg DM/ha/year (R^2=0.30). Annual variations in yield can be attributed to changes in trial locations and trial co-operators over time. However, overall trends towards increasing yield are due to improvements in hybrid genetics, maize agronomy and management practises. Growing and harvesting costs for producing maize silage on an average soil fertility property in the Waikato have increased 3 c/kg DM over 13 years.

Keywords: maize silage, maize grain, *Zea mays*, corn, yield

Introduction

Maize for grain and silage is widely grown in New Zealand, primarily within the North Island for a range of end uses; maize grain for human and animal consumption, and silage principally for animal feed for the dairy industry.

The majority of domestically grown maize grain enters the livestock feed sector, with 58% of grain produced in 2008 being used for poultry, pork and ruminant feed rations (Booker 2009). The remaining 42% was utilised for corn starch manufacturing and human food production. The forecast area sown for maize silage in spring 2015 was 44 500 ha and the forecast area sown for maize grain was 17 400 ha (AIMI 2015).

The average metabolisable energy (ME) value of maize silage in New Zealand is 10.8 MJ ME/kg DM (Kleinmans *et al.* 2016). The ME of maize grain is over 13 MJ ME/kg DM. New Zealand dairy farmers have achieved increased profitability by including maize silage as an energy source into their pasture-based farm systems (Densley *et al.* 2004). There is opportunity to further improve maize silage returns by reducing supplementary feed costs. This can be achieved by continuing to increase crop yield over a wide range of environments. The annual average usage rate of maize silage for animal feed in the dairy industry increased between the 1997-1998 season (193 kg DM/cow) and 2000-2001 season (339 kg DM/cow) (Kolver *et al.* 2001).

Genetic Technologies Limited has been marketing Pioneer® brand maize seed within New Zealand since 1986 and undertakes annual grain and silage strip trials as part of their comprehensive hybrid research programme. The objective of this paper was to quantify the increase in maize grain and silage yield over time and to distinguish the contributing factors and overall benefits to New Zealand agriculture.

Methods

Silage data from 1996-2015 (n=16 600) and grain data from 1991-2015 (n=32 634) were extracted from Pioneer® strip trials. Trials were planted nationally each season for silage or grain with the appropriate comparative relative maturity (CRM) hybrid for the location and environment.

Appropriate maize hybrids were planted in rows that were 76.2 cm apart, using commercial maize planters, in fields provided by cooperating farmers. Each hybrid strip consisted of four rows of 100 m or more in length depending on the field size. Hybrids in strip trials were tested under the cooperating farmer's management conditions, therefore plant population, insecticide, weed and fertiliser management varied by location.

Silage harvest took place when the hybrids were visually assessed (using kernel milk-line score) to be between 30-38% whole plant dry matter content. A uniform section of the crop was selected and the plants from three 5.3 m strips, of one of the middle two rows of each hybrid, were counted, hand-cut at 15 cm above ground level and weighed. A total of eighteen plants (six per strip) were chopped to provide a sample for dry matter determination. A 1 kg sample of chopped whole plant maize was collected and dried at 95°C to a constant weight to determine dry matter content.

Grain harvest took place when the hybrids were visually assessed to be below 30% moisture. The full strip for each hybrid was harvested by a commercial combine and weighed. A 1 kg grain sample was taken and the average of three moisture meter readings used for yield determination adjusted to 14% grain moisture. All analysis was completed in GenStat (Version 18,

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VSN International Ltd, 2015). National average strip data was calculated from the results of the Pioneer® strip trial hybrid programme (between 39 and 2010 data points/year, Table 1). Average trial yield was regressed against year and residuals were plotted to check for non-linearity. These data were also broken down regionally for silage trials to estimate the variation in annual yield increase between maize growing regions in New Zealand.

Weather data were obtained from the NIWA National Climate database, one station was chosen to represent the defined growing region, based on the longevity of the station and proximity to the majority of trials (South Island-Ashburton AWS (26 170), LNI-Palmerston North AWS (3243) and Waikato-Hamilton AWS (2112)). Monthly statistics from 1st October to 30th April for each growing season were extracted for the following weather traits; average daily temperature (˚C), total growing degree days for 10˚C and total rainfall (mm). The residuals of the regional yield data were regressed against the growing season weather conditions to establish any relationship.

Table 1 Number of individual data points for grain (1991-2015) and silage (1996-2015) strip trials.

Harvest year	Grain data points (n)	Silage data points (n)
1991	39	
1992	511	
1993	728	
1994	863	
1995	755	
1996	1234	271
1997	1541	270
1998	1676	278
1999	2010	721
2000	1631	554
2001	1886	690
2002	1125	796
2003	1254	932
2004	900	619
2005	1143	741
2006	1383	854
2007	1546	841
2008	1560	840
2009	1540	879
2010	1449	1171
2011	1589	1210
2012	1707	1496
2013	1656	1223
2014	1648	1356
2015	1260	858

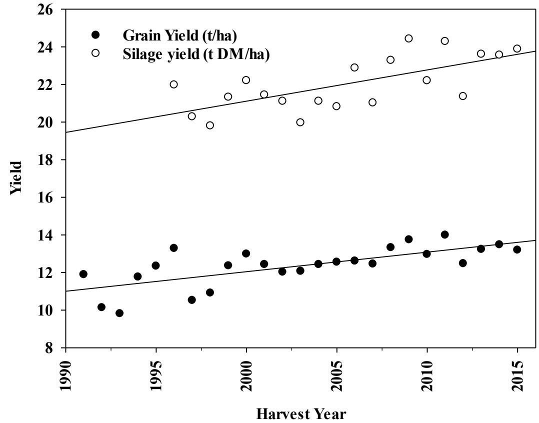

Figure 1 New Zealand maize grain (t/ha based on 14% moisture content) (1991-2015) and maize silage (1996-2015) strip trial yields. Data derived from Pioneer® strip trials (1991-2015). Grain y=0.104x-196.04, R^2=0.501. Silage y=0.166x-310.76, R^2= 0.467.

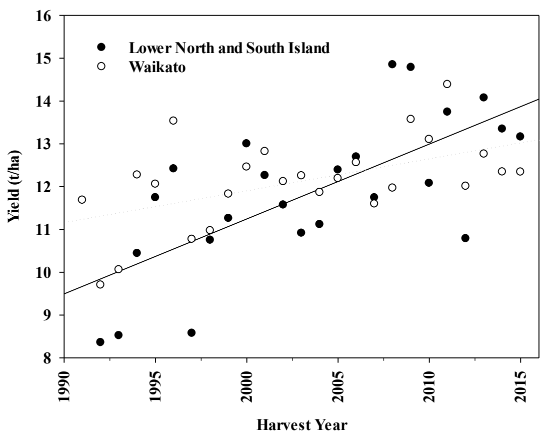

Figure 2 Regional maize grain strip trial yields from 1991 to 2015 in the lower North Island/South Island (y=0.175x-339, R^2=0.482, solid line) and Waikato (y=0.075x-137.26, R^2=0.284, dotted line).

Results

Figure 1 shows national maize grain yields from 1991 to 2015 and silage yields from 1996 to 2015. Based on strip trial results, maize grain has increased on average 104 kg/ha/year (R^2=0.51) in years 1991 to 2015 and maize silage has increased on average 166 kg DM/ha/year (R^2=0.47) in years 1996 to 2015.

Figure 2 shows regional maize grain strip trial yields from 1991-2015 in the Lower North Island (LNI)/South Island and Waikato. Grain yields in the LNI/South Island have increased on average 175 kg/ha/

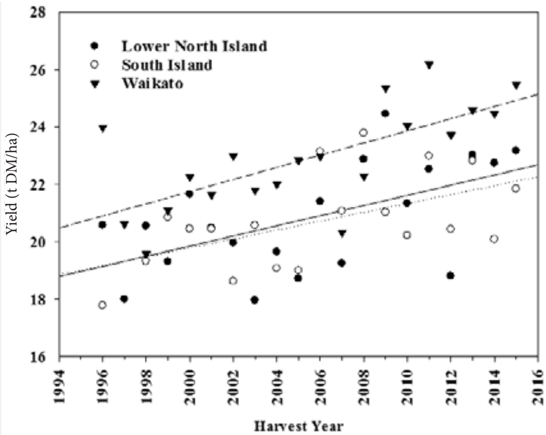

Figure 3 Regional maize silage strip trial yields from 1996 to 2015 for lower North Island (y=0.177x-334.44, R^2=0.309, solid line), South Island (y=0.155x-290.59, R^2=0.296, dotted line) and Waikato (y= 0.212x-402.58, R^2=0.479, broken line).

year (R^2=0.48) and Waikato yields have increased on average by 75 kg/ha/year (R^2=0.28).

Figure 3 shows regional maize silage strip trial yields from 1996 to 2015 for LNI, South Island and Waikato. Yields have increased over time in all regions, with an average increase of 212 kg DM/ha/year (R^2=0.48) in the Waikato, 155 kg DM/ha/year (R^2=0.30) in the South Island and 177 kg DM/ha (R^2=0.31) in the LNI.

Table 2 shows maize silage growing and harvesting costs/hectare on an average fertility soil and Pioneer® average silage strip trial yields in the Waikato from 2002-2003 to 2015-2016. Growing and harvesting costs have increased on average 3 c/kg DM over 13 years.

Table 2 Maize silage growing and harvesting costs/hectare on an average fertility soil and Pioneer® average silage strip trial yields in the Waikato from 2002-2003 to 2015-2016.

Season	Cost ($)	Yield (t/ha)	Cost (c/kg DM)
2002-03	2767	23.0	12
2003-04	2980	21.8	14
2004-05	2997	22.0	14
2005-06	3044	22.8	13
2006-07	3139	23.0	14
2007-08	3235	20.3	16
2008-09	3642	22.3	16
2009-10	3825	25.4	15
2010-11	3832	24.1	16
2011-12	3853	26.2	15
2012-13	3877	23.7	16
2013-14	3800	24.5	16
2014-15	3809	24.5	16
2015-16	3804	24.5	16

The weather data extracted showed a weak relationship with annual yield for all climatic factors measured (Table 3).

Discussion

Maize is the world's largest crop on a tonnage basis (Densley *et al.* 2004) and commercial and independent research programmes have focused on improving yield through the stability of agronomic traits across a wide range of environments. Testing programmes in New Zealand have targeted increased yield through improved genetics as well as crop management practises.

Estimated annual yield of maize grain and silage in New Zealand has historically been increasing (Statistics New Zealand 2010). Yield estimates from national maize grain production data published in Statistics New Zealand National Yearbook before 1991 show an average estimated increase of 170 kg/ha from 1961-1990 (R^2=0.86). This is 66 kg/ha more than results from the on-farm strip trial data from 1991 (Figure 1). Silage yield (t DM/ha) was estimated from grain yield from 1961-1996 as 1.71 times average grain yield (t/ha @14% moisture) and showed that silage yields increased on average 290 kg DM/ha/year (R^2=0.86). This estimated average is also slightly higher than silage strip trial data since 1996. Hardacre *et al*. (1991) state that from 1940-1991 maize grain yield gain in New Zealand has been on average 100 kg/ha/year and suggests that in a 'good year', gains of up to one third greater could be achieved, however, climatic differences among seasons and locations affected growers reaching this potential. This is similar to the national maize grain strip trial average yield gain of 104 kg/ha/year from 1991-2015 (Figure 1).

This national trend of increasing yield is also supported by international literature. Nielson (2012) analysed corn grain yields in Indiana and the United States (U.S.) From 1866-1936, grain yield was constant with no significant annual change in productivity with

Table 3 Coefficient of determination for silage yield residuals regressed against key climatic factors. Data extracted from NIWA National Climate database.

	Sum GDD's at 10˚C (Oct-Apr)	Average air temperature (˚C) (Oct-Apr)	Total rainfall (mm) (Oct-Apr)
Waikato	0.101	0.098	0.036
Lower North Island	0.176	0.180	0.017
South Island	0.002	0.003	0.030

average yields equating to 26 bushels/ac/year (1606 kg/ha/year) (R^2=0.01), due to no breeding advances or improvement in management practises. Hybrid corn was adopted after 1936 and yields increased on average 0.8 bushels/ac/year (50 kg/ha/year) (R^2=0.72) through to 1955. Since the mid-1950s improvements in genetics, agronomy, such as higher planting populations, and crop management has increased U.S. corn grain yields on average 1.9 bushels/ac/year (117 kg/ha/year) (R^2=0.82). Hardacre *et al*. (1991) stated that the greatest historic maize grain yield gains occurred in New Zealand between 1960 and 1980 due to improved crop management practises.

Lauer *et al*. (2001) compared commercial maize silage hybrids released between 1900 and 1997 at three locations in Wisconsin, USA. The study concluded that since 1930, maize silage DM yields have increased between 128 and 164 kg DM/ha/year. This is similar to regional gains within New Zealand over the past 15 years, for example, South Island maize silage yield has increased an average of 155 kg DM/ha/year.

It is estimated that 50-60% of on-farm yield gains in the U.S. are related to genetics (Duvick 2005) and the remainder to management practises. Phenotypic genetic advancement was due to hybrid stress tolerance to abiotic (e.g. heat and drought, cool and wet growing conditions) and biotic (e.g. pest) pressures. Yield potential/plant has not increased over time (Duvick *et al.* 2004) but newer hybrids have increased stress tolerance (Duvick 2005) and therefore a higher number of plants per unit area, producing similar biomass per plant are contributing to improved yield. Duvick *et al.* (2004) states that older hybrids planted at the same plant density as modern hybrids typically have a high percentage of ears with few kernels due to a lower tolerance of plant competition. Newer hybrids are more adaptable to different ranges in soil fertility levels compared to older hybrids (Castleberry *et al*. 1984) and have improved root and stalk strength. Stress tolerance has been a key development in the private sector, where hybrids are tested in hundreds to thousands of yield test plots over many environments before commercialisation (Fischer *et al*. 2014).

Development in management practises over time have benefited maize yield (Pioneer® Growing Point 2016) globally and in New Zealand. An example of a practise in New Zealand which have influenced yield is earlier planting in specific locations and environments, which provides the potential to lengthen the growing season. For example, short maturity hybrids planted primarily in the South Island for maize silage have higher 'early growth' ratings than longer maturity hybrids (Pioneer® Brand Products 2016). This gives flexibility for slightly earlier planting into cooler soil conditions. Other management practises influencing yield are the use of seed treatments containing a fungicide and insecticide, improvements in irrigation practises (e.g. spray irrigation in Canterbury), nitrogen fertiliser management, and planting practises, which result in more uniform stand emergence through consistent depth and seed coverage and equal plant spacing, reducing competition.

Maize silage growing costs have increased slightly over time in New Zealand (Table 2). For example, in the Waikato in 2002, growing and harvesting costs were \$2767/ha (Pioneer® Brand Products 2002) and the average yield (from silage strip trial data) was 23 t DM/ha. In 2015 costs were \$3804/ha (Pioneer® Brand Products 2015) and the average trial yield was 25.5 t DM/ha. This equates to an increase in dry matter cost from 12 c/kg in 2002 to 15 c/kg in 2015. This increase in maize silage cost is modest compared to the Consumer Price Index which lifted 34% over the same 13 year period (Reserve Bank of New Zealand 2016). Research undertaken in the Waikato region in 2008/2009 showed that maize could be grown on high fertility dairy paddocks, including those with a history of effluent application without the need for additional fertiliser (Johnstone *et al*. 2010). For most farmers this will decrease growing costs by around 3 c/kg DM.

The growing environment has and will continue to impact maize grain and silage yields. Weather, abiotic and soil factors throughout the season can influence final yields. Year to year fluctuations from the yield trend are primarily related to weather incidents (Nielsen 2012). The regional climatic data presented in this paper only shows a weak relationship between maize yield and growing degree days, air temperature and rainfall. This is likely due to the weather data from a single location being taken to represent a larger growing region. Nonetheless, the international large scale studies (Nielsen 2012) and empirical farmer knowledge indicates that climate does influence maize yields, whether grain or silage. Future research in quantifying the magnitude of this effect across New Zealand would require a strong research and modelling effort outside of the scope of this study. When taking into account the coefficient of determination (R^2 value) over time, it may not indicate a strong linear increase in yield for regional New Zealand data, however, there is still a trend of increasing yield. The comparison of average weather data from specific years can aid explanation around growing environment effects on yield trend and coefficients of determination. This may include effects of temperature and solar radiation at crucial developmental stages (e.g. flowering and grain fill). Other abiotic factors will also have added to the coefficient of determination including the increased quantity of data points. This is due to an expansion of the research programme and the range of growing environments over time, and the variability in number and location of trial sites year on year. In large multi-year national trialling programmes these factors cannot be avoided.

Historical yield data can provide an indication of future yields, however, it is no guarantee. Based on this and recent trials of commercial maize hybrids within New Zealand, farmers can have confidence that due to product development and advances in agronomy, yield increases will continue. However, the rate of yield increment will be dependent the growing environment which is not consistent from season to season.

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