Frost risk associated with growing maize for silage on Tasmanian dairy farms

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Abstract

The practice of growing maize silage for dairy cows is increasing in popularity within Tasmania. However, due to the relatively high cost of production, the long growing season (c.a. 20 weeks), frost exposure and yield variability, maize is considered precarious to grow. This study explored how long term yield, yield variability and frost risk is mediated by sowing date and maturity type in four dairy regions of Tasmania, Scottsdale (41.17S, 147.49E), Bushy Park (42.71S, 146.90E), Edith Creek (40.99S, 145.08E) and Cressy (41.72S, 147.08E), using the biophysical crop model APSIM. Yields in all regions decreased with later planting dates (median yields decreased from 27 to 14, 23 to 13, 27 to 15 and 25 to 13 t DM/ha with sowing dates of November 12 compared to January 7 for Scottsdale, Bushy Park, Edith Creek and Cressy respectively). Variability in yield increased as sowing was delayed. The regions of Bushy Park and Cressy were identified as locations with a high frost risk while Edith Creek and Scottsdale are relatively risk free. The use of early maturing hybrids reduced the frost risk by 20, 30, 30 and 17% for Scottsdale, Bushy Park, Edith Creek and Cressy respectively. Sowing crops earlier also reduced the risk of frost across all locations. Earlier sown crops and quicker maturing hybrids were also higher yielding than later sown crops and slower maturing genotypes. It is concluded that using early maturing hybrids and early sowing dates are both viable options to manage the risk of frost in maize crops grown in Tasmania.

Key Words

Biophysical modelling, forage crops, cool temperate environments

Introduction

Due to its high yield potential and high water use efficiency (WUE) growing maize for silage is one method of increasing the productivity of land and water on Tasmanian dairy farms (Rawnsley 2007). However, this crop has a particularly high direct cost of production ($2700/ha compared to $760/ha for forage turnips), a long growing season (around 20 weeks in the cool in Tasmania) and requires specialist equipment and skills for successful production (Knox et al. 2006; Rawnsley 2007). These reasons coupled with yield variability and frost exposure mean that the crop is considered precarious to grow. Frost is a particular concern with maize due to its detrimental impact on forage nutritive characteristics. Silage made from frost damaged maize has lower digestibility, poorer fermentation characteristics, higher pH and dry matter content compared to silage made from un-frosted maize (Narasimhalu *et al.* 1986). Nitrogen, potassium, phosphorus and calcium content are all lower in silage made from frosted maize (Stpierre *et al.* 1983).

While field experiments have provided an indication of the expected yield of maize crops grown in Tasmania (Eckard *et al.* 2001; Donaghy *et al.* 2006), these experiments have been limited to providing regional specific information and provided no information as to expected yield variability and the risk of frost damage. While longer term experiments across a range of regions would provide such information, the costs associated with undertaking such studies are prohibitive. A cost effective alternative is to use biophysical models that mechanistically integrate soil, plant, climate and management variables to simulate crop growth and development. This approach has been used successfully to explore the yield potential and WUE of lucerne grown across a range Tasmanian pastoral regions (Pembleton *et al.* 2011), while Robertson *et al.* (1999) have used biophysical modeling to explore the affect of maturity type and sowing date on the risk of frost exposure for canola crops grown in the northern wheat belt of eastern Australia.

The study reported here was undertaken to investigate the risk of frost exposure, long term yield potential and the yield variability of maize crops grown for silage across 4 contrasting dairy regions within Tasmania using the biophysical crop model APISM (Keating *et al.* 2003).

Methods

Validation of APSIM to simulate maze growth in Tasmania

The accuracy of APSIM in predicting the yield of forage maize crops grown in Tasmania was assessed by comparing simulated yield and crop development from APSIM maize to experimental (Donaghy *et al.* 2006) and commercial crop data sets (Rawnsley *et al.* 2007). For each data set, simulations parameters were set to reflect the environmental and management of each crop/experiment. Climatic data for the simulations was either collected on site using weather stations and data loggers (Hobo weather stations, Onset computer company) or as patched point data sets obtained from the SILO database (www.longpaddock.qld.gov.au/silo; Jeffrey *et al.* 2001). The soil parameters for the simulations were either selected as the best match from the already existing Tasmanian soils in APSIM, or, where no match could be found, a new soil was parameterised from known values from that location. Simulated yields were compared to actual observed yields using the using the statistical tests outlined by Tedeschi (2006).

Simulating the growth and frost exposure of maize grown in four dairy regions of Tasmania.
Simulations were developed in APSIM that were reflective of the typical agronomic practices used for the production of forage maize in Tasmania. Sowing date and genotype were the variables used in the simulation. Maize crops were sown into prepared seedbeds at a depth of 30 mm with a pre-planting nitrogen (N) fertiliser application of 100 kgN/ha (applied as urea; 46%N). A side dressing of 150 kg N/ha (as urea) occurred at 45 days after sowing to ensure N did not limit plant growth. In all simulations crops were irrigated. Irrigation was applied on a 20 mm soil water deficit. Planting began on 12 November and occurred at fortnightly intervals until 7 January. Three maize hybrids were planted representing dual purpose forage and grain types. These were Pioneer 3527 (quick maturing; 113 comparative relative maturity rating (CRM)) Pioneer 3237 and Pioneer 3153 (both medium maturing; 116 and 120 CRM respectively). Simulations were run for 46 years (1961/62 to 2006/07) using site specific climate and soil data for the locations of Edith Creek (41.0^{o}S, 145.1^{o}E; red ferrosol soil) Cressy (41.7^{o}S, 147.1^{o}E; red tenosol soil) Busy Park (42.8^{o}S, 146.9^{o}E; black vertosol) and Scottsdale (41.2^{o}S, 147.5^{o}E; brown dermosol soil). To eliminate carry over effects between years, soil surface organic matter, soil nitrogen pools and soil water was reset to initial state for each year. Due to absence of information pertaining to temperatures that cause frost damage to maize crops in Australia, and that frosts occurrence is a function of air temperature, crop temperature, field aspect, crop development and topography, screen temperature thresholds of -1 and -2^{o}C were used as events conducive to frost occurrence as per the methodology of Robertson *et al.* (1999).

Results

APSIM maize predicted crop yield and phenological growth stage with good accuracy (Table 1) being able to explain 70% of the variation in observed values for forage maize yield and phenological growth stage. The model tended to under predict the biomass of forage maize crops with an average difference between the measured simulated mean of 2.86 t DM/ha.

Table 1. Summary statistics indicating the accuracy of APSIM maize when used to predict the yield of maize crops grown in Tasmania.

Summary Statistics	Maize yield (t DM/ha)	Phenological growth stage (APSIM scale)
N	7	5
Measured mean	21.86	8.34
Simulated mean	19.00	7.78
Mean bias	2.86	0.56
r^2	0.70	0.70
Mean prediction error	0.19	0.11
Modelling efficiency	0.24	-0.23
Variance ratio	0.84	0.21
Bias correction factor	0.98	0.40
Concordance correlation coefficient	0.83	0.34

Maize dry matter (DM) yields decreased as planting date was delayed for all environments (Figure 1). Median DM yields decreased from 27 to 14, 23 to 13, 27 to 15 and 25 to 13 t DM/ha with sowing dates of November 12 compared to January 7 for Scottsdale, Bushy Park, Edith Creek and Cressy respectively. Delaying planting also increased the variability in yield as indicated by the increase in coefficients of variation (CV). There was a slight trend for the quick maturing cultivar (Pioneer 3527) to have greater DM yields compared to the medium maturity hybrids (Pioneer 3237 and Pioneer 3153), an effect that was most noticeable for the later planting dates. However, the influence of hybrid on yield was minor compared to influence of planting date.

Risk of exposure to screen temperatures less than -1^{o}C or -2^{o}C increased as planting date was delayed

(Figure 2.). Exposure to these temperature thresholds occurred yearly for the plantings that occurred after 10 December at Cressy and Bushy Park. While the risk of exposure to screen temperatures of -1°C or lower increased with later plantings for Edith Creek or Scottsdale there was only minimal increase in the potential risk of exposure to screen temperatures of -2°C or lower. The quick maturity hybrid (Pioneer 3527) had a lower risk of exposure to a -1°C or a -2°C screen temperature with sowing dates between 12 November and 10 December at all locations. For later sowing dates (24 December and 7 January), this risk was the same for all the hybrids, with the exception of crops grown at Edith Creek and a threshold temperature of -1°C. In this instance the quicker maturing cultivar still had a lower risk of exposure at the later sowing dates.

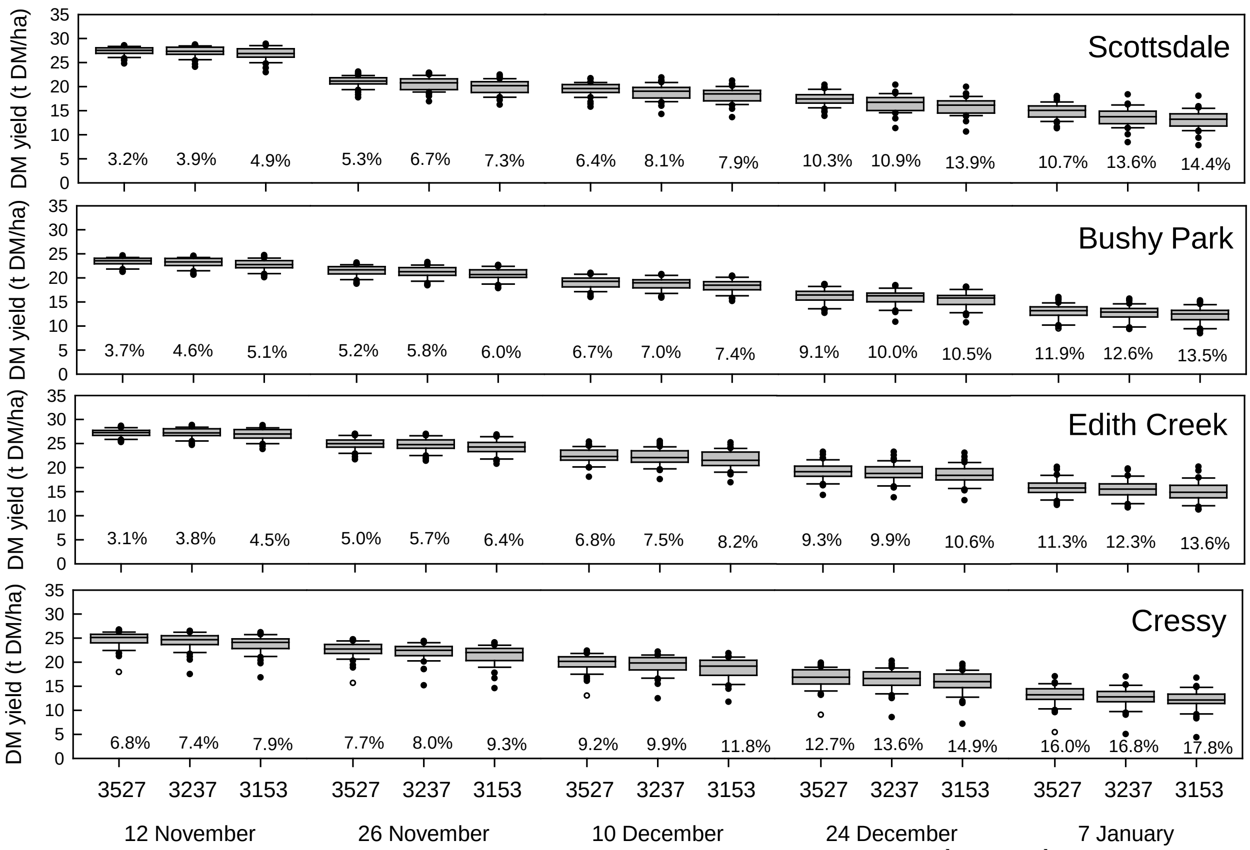

Figure 1. Box and whisker plots (lines represent the median, boxes represent the 25th and 75th percentiles, whiskers represent the 5th and 95th percentiles and dots (•) represent outliers) of the simulated annual DM yield of maize grown for silage with 3 cultivars (Pioneer 3527, Pioneer 3237 and Pioneer 3153) and 5 sowing dates (12 November to 7 January) at 4 locations in Tasmania over 46 growing seasons (1961/62 to 2006/07). Percentage values indicate the coefficient of variation (CV).

Implications and conclusions

The high probability of frost occurrence with late plantings at both Cressy and Bushy Park coupled with the negative impacts of frost damage on the nutritive value of maize silage indicated that late plantings of maize at these locations should be avoided. Earlier sown maize at all locations will have the highest yield potential, highlighting the importance of early planting even at locations that have a minimal risk of frost damage. Earlier maturing hybrids had higher yields and also a lower risk of frost with the earlier planting dates. The development of even quicker maturing cultivars (<113 CRM) should help improve DM yields and minimise the risk of frost further for maize crops grown on Tasmanian dairy farms.

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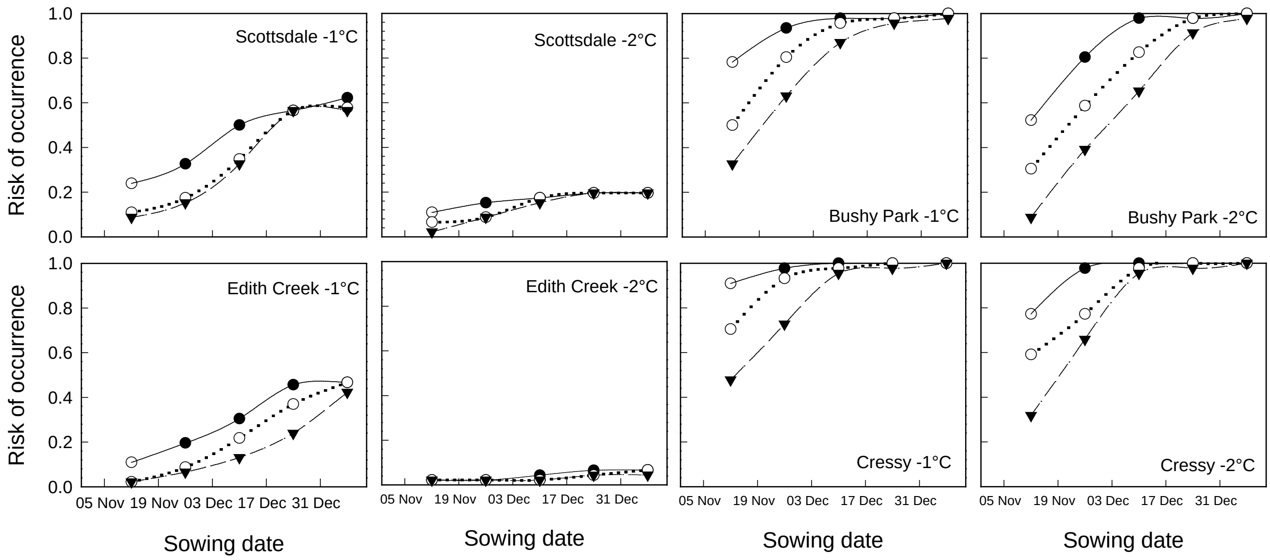

Figure 2. Risk of the occurrence of a frost event (presented as cumulative distribution plots) during the 46 growing season simulations of maze grown for silage with 3 cultivars (Pioneer 3527 (▼), Pioneer 3237 (○) and Pioneer 3153 (●)) and 5 sowing dates (12 November to 7 January) at 4 locations in Tasmania.

References

Knox J, Campbell S, Field B, Thompson R, Hall E (2006) 'Species for Profit: A Guide for Tasmanian Pastures and Field Crops.' (Tasmanian Department of Primary Industries, Water and Environment: Kings Meadows).

Rawnsley RP (2007) A review of fodder crops grown in Tasmania, Invited Paper. In 'Grasslands Society of Southern Australia 16th Annual Conference, Tasmanian Branch'. Launceston, Australia. (Ed. S Campbell) pp. 31-37.

Narasimhalu P, White RP, McRae KB (1986) The Effect of Harvesting before and after Frost on Corn-Silage Composition, and Its Intake and Digestibility in Sheep. *Canadian Journal of Plant Science* **66**, 579-584.

Stpierre NR, Bouchard R, Stlaurent GJ, Vinet C, Roy GL (1983) Effects of Stage of Maturity and Frost on Nutritive-Value of Corn-Silage for Lactating Dairy-Cows. *Journal of Dairy Science* **66**, 1466-1473.

Donaghy DJ, Rawnsley RP, Christie K (2006) Development of a more relevant forage base for the Tasmanian dairy industry, Final report to Dairy Australia. Tasmanian Institute of Agricultural Research, Burnie, Tasmania.

Eckard RJ, Salardini AA, Hannah M, Franks DR (2001) The yield, quality and irrigation response of summer forage crops suitable for a dairy pasture renovation program in north-western Tasmania. *Australian Journal of Experimental Agriculture* **41**, 37-44.

Pembleton KG, Rawnsley RP, Donaghy DJ (2011) Yield and water-use efficiency of contrasting lucerne genotypes grown in a cool temperate environment. *Crop & Pasture Science* **62**, 610-623.

Robertson MJ, Holland JF, Cawley S, Bambach R, Cocks B, Watkinson AR (1999) Phenology of canola cultivars in the northern region and implications for frost risk. In 'Proceedings of the 10th Australian Agronomy Conference'. Hobart, Tasmania.

Keating BA, Carberry PS, Hammer GL, Probert ME, Robertson MJ, Holzworth D, Huth NI, Hargreaves JNG, Meinke H, Hochman Z, McLean G, Verburg K, Snow V, Dimes JP, Silburn M, Wang E, Brown S, Bristow KL, Asseng S, Chapman S, McCown RL, Freebairn DM, Smith CJ (2003) An overview of APSIM, a model designed for farming systems simulation. *European Journal of Agronomy* **18**, 267-288.

Rawnsley RP, Donaghy DJ, Fergusson M (2007) Monitoring yield, field quality and water use efficiency of irrigated summer forage crops (maize and turnips) on commercial dairy farms, Final report to DairyTas. Tasmanian Institute of Agricultural Reaserch, Burnie Tasmania.

Jeffrey SJ, Carter JO, Moodie KM, Beswick AR (2001) Using spatial interpolation to construct a comprehensive archive of Australian climate data. *Environmental Modelling and Software* **16**, 309-330

Tedeschi LO (2006) Assessment of the adequacy of mathematical models. *Agricultural Systems* **89**, 225-247.