Field Crops Research 150 (2013) 135–144

Contents lists available at SciVerse ScienceDirect

Field Crops Research

journal homepage: www.elsevier.com/locate/fcr

The effect of planting date on maize grain yields and yield components

Rowland Tsimba[a,*], Gregory O. Edmeades[b], James P. Millner[c], Peter D. Kemp[c]

[a] Genetic Technologies Ltd., PO Box 105-303, Auckland 1143, New Zealand
[b] 43 Hemans St, Cambridge 3432, New Zealand
[c] Institute of Agriculture and Environment, Massey University, Palmerston North 4474, New Zealand

ARTICLE INFO

Article history:
Received 12 July 2012
Received in revised form 25 May 2013
Accepted 27 May 2013

Keywords:
Leaf area index
Maize grain yield
Kernel weight
Kernel number
Harvest index
Planting date

ABSTRACT

Four experiments were established in the Waikato and Manawatu regions of New Zealand in 2006 and 2007 to determine planting date (PD) effect on maize (*Zea mays* L.) leaf growth, grain yield (GY) and yield components. Five or six hybrids of three maturity classes (early, mid and late) were sown on four or five PDs between 18 September and 15 December of each year. Increasing mean daily temperatures in the range 13–19 °C immediately prior to tassel initiation reduced leaf number by 0.1 leaf °C^{-1}. Highest leaf area indices were observed at mean daily temperatures of 17–19 °C. In the lower latitude environment of Waikato, maximum GY was obtained with earlier plantings than Manawatu. Lower spring temperatures, and consequently smaller canopy sizes in Manawatu depressed yields of early plantings. When planted early, late hybrids generally outyielded early hybrids while a better balanced source–sink ratio meant that early hybrids yielded consistently across PDs, matching or outyielding late hybrids when both were planted late. Lower grain filling mean temperatures (15 vs. 18 °C) and average radiation (11 vs. 20 MJ m^{-2} d^{-1}) reduced yields more for late than early plantings. Grain yield was highly correlated with kernel number (KN) (r = 0.90***) and weight (KW) (r = 0.76***). Lowest KN, KW and GY values were obtained under late plantings, low rainfall (<20 mm) and/or radiation (<18 MJ m^{-2} d^{-1}) 10–20 d either side of flowering, or when mean temperatures ≤15 °C or irradiance <11 MJ m^{-2} d^{-1} occurred during grain filling. Kernel number, KW and GY responses to late planting or water stress were more apparent in late than early hybrids. Kernel weight was more stable than KN under late planting or water stress conditions. Water stress during grain filling affected late PDs more than early PDs. Total biomass and harvest index decreased with delayed planting.

1. Introduction

Environmental factors such as temperature, radiation and water vary in a random manner around their seasonal mean trends, resulting in uncertainties in crop production during the main cropping season. The biggest challenge is to determine the ideal time for planting either early or late season hybrids, especially when planting window is shortened by weather or management challenges. Because of differences in maturity and length of growing seasons, the ideal planting dates (PDs) for maize (*Zea mays* L.) hybrids vary among locations and seasonally within locations. To maximise yields and profitability it is however essential that the maize hybrid with the right maturity be selected for planting given the planting window available to the farmer.

Research has shown a yield penalty from planting early hybrids if season length was sufficient for later maturing hybrids (Sorensen et al., 2000). Early maturing hybrids usually fail to fully utilise available solar radiation for the period when temperatures are suitable for growth and therefore will not realise the full yield potential of the growing season and the inputs provided by the grower (Lauer, 1998). Similarly, late hybrids may fail to mature before the first killing frost occurs. When planted late, early hybrids could equal, or outperform full season hybrids (Staggenborg et al., 1999). Early hybrids may also be more profitable since later hybrids may require additional artificial drying for safe storage.

Environment by crop growth or development interactions influence crop cycle duration and yields differently. For instance, if intercepted photosynthetically active radiation (IPAR) levels per plant around flowering are low, kernel set declines and harvest index (HI) may be significantly reduced. Under favourable growing conditions, assimilate production rate, which determines maize yields, is driven by IPAR and leaf photosynthetic rate (Monteith, 1977). Radiation interception is largely determined by leaf area

Abbreviations: ASI, anthesis-silking interval; ENV, environment; GY, grain yield; HI, harvest index; IPAR, intercepted photosynthetically active radiation; KN, kernel number; KW, kernel weight; LA, leaf area; LAI, leaf area index; NIWA, National Institute of Water and Atmospheric Research; PD, planting date; PM, physiological maturity; RUE, radiation use efficiency; TI, tassel initiation.

* Corresponding author. Tel.: +64 7 839 2734; fax: +64 7 839 2735.
E-mail addresses: rowland.tsimba@gmail.com, rtsimba@genetic.co.nz (R. Tsimba).

0378-4290/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.fcr.2013.05.028

index (LAI) which in turn is influenced by genotype, nitrogen and water supply, temperature and photoperiod (Muchow and Carberry, 1989).

High grain yields (GYs) result from an increased availability of assimilate supply (source) for grain setting and grain filling accompanied by an enhanced capacity of the kernels (sink) to accommodate those assimilates. Source–sink balance alters when crops are planted either early or late. Kernel number is usually strongly associated with GY (Otegui et al., 1995; Bolaños and Edmeades, 1996) and therefore defines sink size. Kernel numbers per plant are largely determined by conditions that occur around silking time (Andrade et al., 1993; Kiniry and Knievel, 1995) and therefore have a large bearing on GY. Low temperatures encountered with early planting tend to reduce plant height (Al-Darby and Lowery, 1987) mainly by decreasing internode length and less so by reducing leaf numbers. Leaf area (LA) is also considerably lower.

Yield reductions due to early or late planting are well documented in the literature (e.g. Johnson and Mulvaney, 1980; Sorensen et al., 2000). While early planting results in reduced IPAR because of delayed LA development, high temperatures under late planting situations also reduce IPAR in the two week period either side of flowering by reducing calendar time for crop development, thereby decreasing yields (Otegui et al., 1996). Cool nights during grain filling, common under late planting situations, may also reduce radiation use efficiency (RUE) (Jones et al., 1986).

In situations where mid-season drought is likely to occur, late planting can also expose crops to water deficits during flowering. This may delay silking, increasing the anthesis-silking interval (ASI) resulting in reduced sink size through poorly pollinated ears, or through abortion of kernels and ears (Bolaños and Edmeades, 1996). Anthesis-silking interval is a predictor of seed set in many maize cultivars when under stress at flowering (Edmeades et al., 2000). Drought effects can thus be minimised by adjusting planting time and hybrid maturity so that flowering occurs when drought risk is judged to be minimal.

Where planting has been delayed, or where hybrids are being sown in new and untested areas, knowledge of how the maturity of the hybrid interacts with its response to variable environmental conditions is key to developing mitigating strategies required to optimise and stabilise yields. If these relationships are generally known, they can be used to develop response functions to PD by hybrid, and craft a strategy that will maximise farmers' incomes.

The objective of this study was to determine how PD and the environment (ENV) affect harvest index (HI), sink and source size, barrenness and consequently grain and total biomass yields of maize hybrids differing in maturity in a cool temperate climate. The study is part of a more extensive investigation that forms the basis of adapting the CERES Maize model to predict an optimal match of hybrid and environment when planting maize in a temperate climate (Tsimba, 2011).

2. Materials and methods

2.1. Site details

Four replicated experiments were established over two growing seasons at three locations in New Zealand. These were at Rukuhia Research Station (37.86°S, 175.32°E; 50 m asl) in 2006 (RUK07) and 2007 (RUK08), Ngaroto Research Station (37.98°S, 175.32°E; 84 m asl) (NGA08) and Massey University Pasture and Crop Research Unit (40.38°S, 175.58°E; 18 m asl) in 2007 (MAS08). The latter was situated in the Manawatu Region on a Manawatu fine sandy loam (Dystric Fluventric Eutrochrept). Both Rukuhia and Ngaroto Research Stations are situated in the Waikato Region on a Horotiu sandy loam soil (Vitric Orthic Allophanic) and an Ohaupo silt loam (Typic Orthic Allophanic), respectively (Hewitt, 1998).

The Manawatu site had a history of long term pasture whereas both Waikato sites had been in long term maize monoculture for up to 25 yr. The history of the Waikato sites closely mirrors a typical farming system common in New Zealand for maize grain production, while Manawatu more closely characterises silage production under a dairy farming system. The selected sites can also be considered to be a fair representation of soil and weather conditions for their respective regions. Rukuhia and Ngaroto respectively typify low and high potential yielding sites for their regions, and differ mainly in soil type. Because of its higher latitude, the Manawatu site experiences a shorter growing season with cooler mean spring temperatures and a more rapid decline in solar radiation and temperature during the autumn, compared to the Waikato sites.

2.2. Planting details and experimental design

Five and four PD treatments were established at the Waikato ENVs and MAS08, respectively. The range of PDs and ENVs evaluated in this study were designed to create contrasting environmental conditions that represent a wide range of situations for maize growth and development. Planting dates were thus widely spread to include very early, typical and very late PDs for each ENV, and were as follows:

RUK07 – 18 September, 11 October, 2 November, 24 November, and 15 December, 2006.
RUK08 – 20 September, 13 October, 1 November, 22 November, and 13 December, 2007.
NGA08 – 21 September, 11 October, 1 November, 22 November, and 13 December, 2007.
MAS08 – 16 September, 6 November, 23 November, and 10 December, 2007.

Hereafter, PD treatments will be referred to as PD1, PD2, PD3, PD4 and PD5, respectively. At MAS08, PD1 was considered missing in subsequent data analyses.

Six single cross hybrids representing three maturity groups of comparative relative maturity (CRM) ratings of 91–110; short season (38P05 and 38H20), mid season (36M28 and 36B08) and full season (34D71 and 34P88) were planted in the Waikato ENVs. Hereafter, hybrid maturities will be referred to as early, mid and late, respectively. Hybrid maturity designations varied with ENV. At MAS08, 36M28, 36B08 (late), 38H20, 38P05 (mid) and 39G12 (early) were planted. The CRM ratings from hybrids planted at MAS08 ranged between 78 and 103. The later maturity hybrids sown in the Waikato were considered too late and not adapted to the Manawatu Region, whereas 39G12 was regarded as too early for the Waikato ENVs. These hybrids were selected from a pool of 29 Pioneer® hybrids that are commercially available in New Zealand, and are representative elite hybrids for their maturity classes.

Prior to planting, soil tests were conducted on each ENV to determine the nutrient level of each field. Soil pH, Olsen P, cation exchange capacity (CEC), base saturation, sulphate-S, total C and N and organic matter in the upper 60 cm were determined in order to calculate fertiliser and lime requirements needed to ensure non-limiting nutrient supply (Edmeades et al., 1984). Soil water contents and bulk density for each soil horizon within the profile for each PD treatment were measured gravimetrically at or prior to planting. The soil samples were obtained from three horizon layers (0–20 cm, 20–45 cm and 45–65 cm) using soil cores of 4.8 cm diameter by 5 cm height, taken from the midpoint of each horizon. The samples were weighed immediately and oven dried to constant weight at 105 °C.

In early spring, the first experiment (RUK07) received 92, 50 and 50 kg ha^{-1} of N, P and K, respectively, as base fertiliser in the