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Maize (*Zea mays* L.) response to sowing timing under agro-climatic conditions of Latvia

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Abstract

Maize (*Zea mays* L.) is a comparatively new field crop grown in Latvia (extensively grown only since 1954). Some crop failures caused by adverse meteorological conditions frequently have been more expressed when inappropriate agricultural management practices were used. The importance of sowing time has been widely investigated in many countries, and the conclusion has always been that a higher yield can be obtained if sowing is done on the date which is the possibly earliest for a specific country. The aim of the present research, carried out during 2005–2008 at the Research and Study Farm Vecauce of the Latvia University of Agriculture, was to specify maize sowing date in Southwest Latvia and to analyse maize development depending on sowing time. Field trials with four maize hybrids ('Earlystar', RM-20, 'Tango', and 'Cefran') sown on four dates (25 April, 5 May, 15 May, and 25 May) were carried out on *Luvic Epigleyic Phazeozem* (*Calcaric*), lvPH (glp:ca). Maize was harvested also on four dates starting with 1 September at ten-day intervals. Results showed that earlier sown maize needed more days till emergence and from emergence till silking. Number of days from silking till maturity stage, when 250 g kg^{-1} of dry matter (DM) content was achieved, depended on the hybrid, but not on the sowing date. Number of accumulated growing degree days for entering specific development stage was not dependent ($p > 0.05$) on the sowing date. Plants were taller and stand density was higher if maize had been sown late (25 May). The best and significantly ($p < 0.05$) higher average DM yield was obtained when maize had been sown on 5 May (14.34 t ha^{-1}). Average yields were lower and similar (13.28–13.47 t ha^{-1}) when maize had been sown both earlier and later. Sowing time had a slight, but significant ($p < 0.05$) effect on DM, crude protein, neutral and acid detergent fibre content, net energy for lactation (NEL) and the proportion of ears in the whole DM yield, and the results were better if maize had been sown earlier. The research allows us to conclude that the best sowing time of maize in central and western part of Latvia is around 5 May. If a decision is to grow late maturity hybrids, then sowing in the last days of April has to be considered.

Key words: *Zea mays*, sowing date, meteorological conditions, hybrids, yield, quality, harvesting date.

Introduction

Maize (*Zea mays* L.) is one of the newest crops grown in Latvia: the very first published data on maize growing can be found in late 19th century, but its more extensive growth for forage started in 1954 (Gaile, 2009). Maize is a crop of southern origin and, due to this, is mainly grown between latitudes 30° and 55°, and relatively little grown at latitudes higher than 47°. Latvia is located between the North latitudes 55° and 58° and can be considered as a marginal area for maize growing. For high quality silage making every step of the cultivation technology is important and maize reaction to even slightly adverse meteorological or crop management conditions is more expressed if compared with crops traditionally grown in Latvia, e.g., small grain cereals. It could be one of the reasons why during the last two decades the maize sowing areas have drastically changed – starting from an initially rapid decrease from 44.8 thousand ha in the year 1990 to only 500 ha in 1997 and 1998, and unevenly increasing again during the last few years (2009 – 9.8 thousand ha, 2010 – 7.1 thousand ha). It has been observed that maize sowing areas decrease if crop growing conditions have been unfavourable in the previous year, which leads to lower yield than expected.

Sowing time is critically important for any grower, but that advised earlier in Latvia – middle of May – can be too late, especially due to some changes in climate and availability of more cold-tolerant hybrids. Much research on maize sowing time has been carried out in other agro-meteorological conditions mainly taking into account the yield of grain, and not of silage (Lauer et al., 1999; Racz et al., 2003). In most cases, earlier sowing has had a positive effect on maize yield. In 1966, Rossman and Cook (cited in Racz et al., 2003) carried out an experiment and sowed the maize on two dates in a ten-day interval: the first date was the most favourable date, but the second – ten days later. The researchers observed that the grain yield reduced by 9% when sowing had been delayed by 10 days. Gaile (2004) has reported that dry matter (DM) yield of the whole maize plant in Latvia during four years was reduced by 7% to 12% when sowing was done 10 days later than the optimum, most preferable date for each specific year. Gaile (2004) has also determined that early planting depends on the conditions of a particular season, mainly on air temperature, and is one of the keys to growing silage maize in Latvia. However, this research did not specify the optimum sowing date. It only indicated that a delay in planting can cause reductions in yield along with quality. In completely different conditions (Portugal; Braga et al., 2008) it is advised to use diverse planting dates for various maturity hybrids – to sow late maturity hybrids early for higher yield, and to sow early maturity hybrids later to optimize silage quality. Also Lauer et al. (1999) suggest planting later maize hybrids early because the full growing season can be used and hybrids can mature before autumn frosts. Abdel Rahman et al. (2001) in Sudan and Avcioglu et al. (2003) in Turkey have found that earlier sown maize yielded significantly more. Of course, the terms 'early' and 'late' have to be specified for any specific growing conditions. Literature data shows that for each location an optimum maize sowing date exists and sowing before and after this date results in yield reduction (Lauer et al., 1999).

The aim of the present paper is to analyse development of maize grown for silage, DM yield and quality as affected by sowing date, and to more accurately define the optimum maize sowing time in Southwest of Latvia. The hypothesis was presumed that sowing maize earlier (very last days of April till early May) will ensure higher yield with better quality. Results of the first three trial years (2005–2007) with an emphasis on maize quality changes depending on sowing time were reported in a poster session of the 22nd General Meeting of the European Grassland Federation and published in the conference proceedings (Gaile, 2008). The current article supplements the earlier published results with the data of another trial year and gives broad analysis on maize development and yield, which was not possible previously.

Materials and methods

To clarify maize sowing time in Latvia, field experiments funded by the grant of the Latvian Council of Sciences were carried out at the Research and Study Farm Vecauce (latitude: N 56°28′, longitude: E 22°53′) of the Latvia University of Agriculture during 2005–2008. Three-factor field trials were arranged in a randomized complete block design with four blocks with an individual plot size of 16.8 m^2 and four rows in each plot. Soil at the site was *Luvic Epigleyic Phazeozem* (*Calcaric*), lvPH (glp:ca), fine sandy loam with pH KCl of 7.1, available P content – 252 mg kg^{-1}, available K – 198 mg kg^{-1}, and humus content – 25 g kg^{-1}.

Traditional soil tillage was used including mouldboard ploughing in the previous autumn along with cultivation and rototilling before sowing in spring. Original seed of four maize hybrids (factor A; effect of hybrid is not analyzed in detail in this paper) with different maturity ratings defined by the FAO number ('Earlystar', "Euralis Semences", France), FAO 160; RM-20 ("Euralis Semences", France), FAO 180; 'Tango' ("Südwestsaat" GbR, Germany) – standard, FAO 210; and 'Cefran' ("Oseva", Czech Republic), FAO 340) was used. A lower FAO number means an earlier maturity. Maize was sown on four dates (factor B) starting on April 25 at ten day intervals until May 25 in each year. Planted population density was 82 000 plants ha^{-1} (distance between rows was 0.70 m, distance between plants in a row – ~0.17 m). A special hand-operated planter was used for sowing. Fertilizers applied before sowing were: 34 kg ha^{-1} P, 75 kg ha^{-1} K, and 18 kg ha^{-1} N. Nitrogen top-dressing (ammonium nitrate) was done twice: 1st time when the herbicide influence on weeds was noticeable (70 kg ha^{-1} N), and the 2nd time – when maize was 50–60 cm tall (60 kg ha^{-1} N). Weeds were controlled with herbicides at maize 3–6 leaf stage, and later on mechanically – using a hoe for those which had not disappeared. Herbicides used in 2005 and 2006 were Nicosulfuron (40 g l^{-1}) 1.0 l ha^{-1} + Dicamba (480 g l^{-1}) 0.3 l ha^{-1}, but in 2007 and 2008 – Tritosulfuron (250 g kg^{-1}) + Dicamba (500 g kg^{-1}) 200 g ha^{-1} + Rimsulfuron (250 g l^{-1}) 30 g ha^{-1}, and after 10 days – Clopyralid (300 g l^{-1}) 0.4 l ha^{-1}. Harvesting was done on four dates (factor C; results on the influence of harvesting date are not widely analyzed in this paper) beginning with 1 September and continuing at ten day intervals (10 September, 20 September, and 1 October). During three harvesting dates (1 September, 10 September, and 1 October), the yield was determined from 0.7 m^2, but during the main harvesting on 20 September – from 8.4 m^2. Plants were cut 15 cm above the soil surface and weighted, and the samples were taken for analyses.

During the growing season, the following observations were done: 1) full emergence (when 75% of the sown seeds emerged), 2) field germination in percent of the sown seeds, 3) full flowering of female flowers, i.e. silking (when 75% of emerged plants had visible silk), 4) number of plants before harvesting. Observations were done in the two middle rows. Plant height (m) was measured from soil level till the top of tassel for 20 successive plants in the same row before main harvest on 20 September.

Dry matter (DM) yield (t ha^{-1}) of the whole plant and ears (cob + corn) was calculated from fresh matter yield and DM content. DM content (g kg^{-1}) was determined on each harvest date according to ISO 6496:1999 method – separately for ears, stover (stem + leaves) fraction, and the whole plant. Proportion of ear DM yield in the whole plant DM yield (g kg^{-1}) was calculated. Crude protein (CP) content was measured according to the Kjeldahl method and using coefficient 6.25 (LVS EN ISO 5983-2:2003); neutral detergent fibre (NDF) in DM (g kg^{-1}) was established using the Forage analyses method 2.2.1.1.; acid detergent fibre (ADF) – using the Forage analyses method 4.1. Some parameters were calculated using formulas (1) and (2):

net energy for lactation: NEL, MJ kg^{-1} of DM = (0.00245 × DDM − 0.12) × 4.184, (1),

where DDM is digestible dry matter calculated from ADF:

DDM, g kg^{-1} DM = 889 − (0.779 × ADF) (2).

Meteorological conditions were variable in the research years, but on average suitable for maize growing. Most frequently temperature conditions are a limiting factor for maize growing in Latvia, but during the research period they were quite appropriate. Average day and night temperature from 25 April (1st sowing date) till 30 September was 14.4°C in 2005, 15.7°C in 2006, 14.8°C in 2007, and 13.9°C in 2008 (Table 1 shows period from 1 May till 30 September). Also the sum of active temperatures (above 10°C) was calculated to characterize the temperature conditions during research years. From 1 May till 30 September it was as follows: 2069°C in 2005, 2299°C in 2006, 2136°C in 2007, and 1944°C in 2008. The author's experience shows that active temperature sum of at least 1900 °C is needed to achieve adequate maturity. Sum of precipitation during the same years and the same period was 298, 267, 339, and 230 mm, respectively. Even though the sum of precipitation seems to be sufficient, the year 2006 was very dry till August (Table 1) and maize suffered from drought stress; lack of precipitation did not allow utilizing the extremely good temperature conditions and caused yield decrease. Besides, spring frost after maize emergence on 1 June 2006 caused evident stress on plants.

Table 1. The temperature and precipitation compared with the meteorological norm during 2005–2008*

Month	Temperature, °C					Precipitation, mm				
	2005	2006	2007	2008	Norm	2005	2006	2007	2008	Norm
May	11.2	11.6	12.3	11.3	11.2	43	28	52	24	43
June	14.3	16.2	16.6	14.6	15.1	49	24	49	44	51
July	18.3	20.1	16.3	17.1	16.6	65	13	102	57	75
August	16.1	17.5	17.9	16.4	16.0	106	150	60	90	75
September	13.3	13.9	11.9	10.6	11.5	36	46	76	15	59
On average	14.7	15.9	15.0	14.0	×	Σ298	Σ261	Σ339	Σ230	Σ303

Note. * – data of temperature and precipitation were recorded directly on the research field by an automatic meteorological station, but long-term average data (norm) were taken from Dobele Hydro-meteorological Station.

Growing degree days (GDD) were calculated using formula (3) (Shaw, 1988) and are analysed in more detail in the next section in connection with maize development.

GDD = ((daily max temp. + daily min temp.) /2) – 10°C (3).

If the maximal temperature is higher than 30°C, then 30°C is used in the equation, and if the minimal temperature is lower than 10°C, then 10°C is used as the minimal temperature (Shaw, 1988).

Strong autumn frosts occurred on 17 and 18 September 2005 when maize was heavily damaged, and after the frost rapid drying of maize grain and the whole plant was observed.

Overall, the best year for maize growing during the research period was 2007 when temperature conditions already in the first half of the growing season were favourable and distribution of precipitation was even.

The results were statistically analyzed using standard analysis of variance methods for a 4 × 4 × 4 factorial arrangement of treatments in a randomized complete block design. *Student's* criterion was used for multiple comparison procedures. LSD at $p < 0.05$ was calculated. Also two-factor analysis of variance, correlation and regression analysis methods were used.

Results and discussion

Development of maize. Duration of *maize emergence* depended significantly ($p < 0.05$) on the sowing date – earlier sown maize needed more days till full emergence: on average per four years, maize sown on 25 April emerged after 18 days, sown on 5 May – after 15 days, sown on 15 May – after 12 days, and sown on 25 May – after 8 days. Data of Keane (2002) shows a significant effect of the sowing date on emergence of maize seedlings, but only in one year the conclusion was absolutely identical to above-described results: emergence occurred more rapidly when sowing date was delayed. It is well known that warmth and moisture are critical factors for an even and quick emergence. During the trial, lack of moisture at the time of emergence was not observed and temperature was mainly a limiting factor. Such a conclusion has been reached also in other marginal sites (Crowley, 2005). As shoot apex remains below the soil surface until about 6-leaf stage, both the shoot and root development are directly influenced by the soil temperature in the early development stages (Keane, 2002; Crowley, 2005; Hund et al., 2008). Accordingly, soil heat management has to be taken into account: if soil warms up more quickly, sowing can be done earlier (Menyhert, 1985, cited from Racz et al., 2003).

Seed germination rate is mainly connected with soil temperature at the depth of seed placement. In our research, soil temperature was measured at 10-cm depth by an automatic meteorological station. A strong substantial ($p < 0.05$) negative correlation was found between the soil temperature at 10-cm depth and the number of days from sowing till full emergence (Fig.).

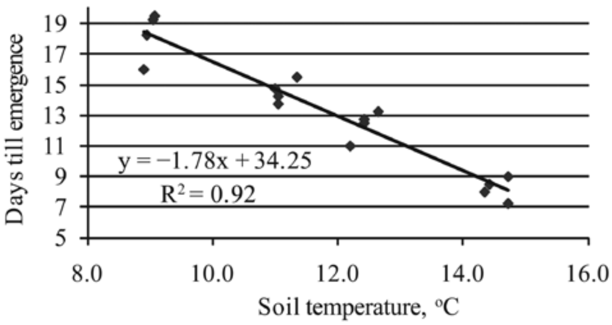

Figure. Correlation between soil temperature at 10-cm depth and number of days from maize sowing till full emergence

It was observed that for full emergence maize accumulated on average 49 GDD. The number of accumulated GDD varied slightly depending on the sowing date (from 45 (maize sown on 25 May) till 51 (maize sown on 25 April and 15 May)), but the influence of hybrid or sowing date on the accumulated number of GDD was not substantial.

Average four-year and four-hybrid field germination was 89% if maize was sown on 25 April and 5 May, 90% if sown on 15 May, and 92% if sown on 25 May. Although mathematically field germination was significantly ($p < 0.05$) better if maize was sown on 25 May, from the agronomical point of view the difference was unimportant. It means that early sowing even in adverse conditions (low soil and air temperature) did not cause any important field germination reduction if seed quality was good. Only for hybrid RM-20, temperature conditions on the first and second sowing date in year 2007 caused a reduction in field germination down to 64–65%. Seed of this hybrid had good germination ability (field germination on 3rd and 4th sowing date was again above 80%), but probably lower germination energy, and seed perished when placed into cool soil. This experience shows that for early maize sowing only high quality seed is needed, which is in accordance with the findings from the literature (Racz et al., 2003). If there is some doubt about seed quality, sowing should be done when soil has become warmer. Also spring frost risk exists for early sowing, and growers should know and take into consideration long-term spring frost observations in their farm or even in a specific field. It can be also good to obtain data about specific hybrids' cold tolerance, because research findings show that extremely cold-tolerant hybrids start to develop even at the temperature of 4°C, whereas other hybrids require at least 8°C (Marton, 1997, cited from Racz et al., 2003). It has been found that use of a plastic film in cold spring conditions or in early sowing dates can improve emergence of maize (Keane, 2002), which, in turn, also improves DM yield, DM content, and ear proportion in DM yield.

According to Lauer et al. (1999), sowing date does not consistently affect plant density at harvest: low densities had occurred with equal frequency when maize was sown on different dates. In our trial, average-per-all-trial-years plant density at harvest was similar in plots sown on the first three sowing dates (73680–74810 plants ha^{-1}), but was substantially ($p < 0.05$) higher when maize was sown on 25 May (77 010 plants ha^{-1}). This was logical because field germination as initial cause of plant density at harvest strongly correlated with the number of plants ($p < 0.05$); however, in 2005, the largest number of plants per 1 ha was observed in the plots sown on 25 April.

Silking of maize was observed from the last ten-day period of July till early August for earlier hybrids ('Earlystar', RM-20, and 'Tango') depending on the sowing date. The earliest silking date of the latest hybrid 'Cefran' was observed on 1–2 August 2007 in the plots sown on 25 April and 5 May. When 'Cefran' was sown on 25 May, silking was observed on 11–14 August in 2006, 2007, and 2008, but in the year 2005 – only on 20 August. From maize emergence till full silking it was necessary to accumulate 478 GDD on average per all hybrids, years, and sowing dates. The number of accumulated GDD was not dependent on the sowing date ($p = 0.64$), but was substantially dependent on the hybrid used: latest hybrid 'Cefran' (FAO 340) needed 518 GDD, whereas 'Earlystar' (FAO 160), RM-20 (FAO 180) and 'Tango' (FAO 210) needed 470, 461 and 463 GDD respectively ($LSD_{0.05} = 40$). The number of days necessary for accumulation of such a number of GDD was significantly ($p < 0.05$) dependent on the hybrid and the sowing date – earlier sown maize required more days from emergence till silking: 79 (sown on 25 April), 74 (sown on 5 May), 70 (sown on 15 May), and 67 (sown on 25 May) days. A tendency was observed that earlier sown maize on average needed more GDD from emergence till full silk phase: maize sown on 25 April accumulated 492 GDD, sown on 5 May – 478 GDD, sown on 15 May – 475 GDD, and sown on 25 May – 467 GDD.

The next very important step for maize development is ripening for at least up to the stage when DM content of fresh matter reaches 250 g kg^{-1}. The results showed that from silking to maturity stage with DM content of 250 g kg^{-1}, three earlier maize hybrids needed 38–44 days during which on average 257 GDD were accumulated. Neither hybrid nor sowing date significantly ($p > 0.05$) influenced the number of days till the required maturity stage or accumulated GDD. The only tendency observed was that 'Earlystar' (39 days) needed fewer days if compared with RM-20 (43 days) and 'Tango' (41 day). The latest maturity hybrid 'Cefran' did not achieve DM content of 250 g kg^{-1} in fresh matter in all plots sown in 2005, in the year 2007 – only in plots sown on 25 May, and in 2008 – in plots sown on 15 and 25 May (Table 2). The average results of the data on 'Cefran' showed that the hybrid needed at least 47 days to reach the required maturity stage. It means that for such hybrid in years, when maize growing conditions are inappropriate or maize is sown late, harvesting should be delayed until October.

Table 2. The date when hybrids achieved DM content of 250 g kg^{-1} depending on the sowing date

Sowing date (B)	Hybrid (A)			
	'Earlystar' FAO 160	RM-20 FAO 180	'Tango' FAO 210	'Cefran' FAO 340
25 April	1–15 Sept.	1–20 Sept.	1–15 Sept.	10–25 Sept., except 2005
5 May	1–15 Sept.	5–20 Sept.	1–15 Sept.	20–28 Sept., except 2005
15 May	5–20 Sept.	10–20 Sept.	10–20 Sept.	20–30 Sept., except 2005 and 2008
25 May	10–25 Sept.	10 Sept.–1 Oct.	10 Sept.–1 Oct.	20 Sept., except 2005, 2007, 2008

The results also showed that approximate harvesting time can be predicted by silking date: 40–47 days after full silking of maize.

A better DM content for preparation of good quality maize silage is 280 g kg^{-1}, and such maturity stage can be reached in September if maize is sown on earlier dates – 25 April and 5 May. A little more risky seems to be 15 May, whereas sowing as late as on 25 May can be allowed only when such early hybrids as 'Earlystar' are used (Table 3). Also literature data indicate increased maize moisture when sown on later dates (Lauer et al., 1999; Keane, 2002; Gaile, 2004).

Calculation of average GDD per growing season (from sowing till maturity stage when DM content of 250 g kg^{-1} was reached) showed that sowing date had not influenced the sum substantially (p = 0.26): 759 GDD for 'Earlystar', 779 GDD for RM-20, and 771 GDD for 'Tango' (hybrid influence was not substantial, p = 0.56). The average sum of GDD for 'Cefran' (calculated from data when above-mentioned maturity stage was achieved) was 842.

The total number of GDD from 25 April till 1 October was as follows: 834 GDD in 2005, 1012 GDD in 2006, 898 GDD in 2007, and 774 GDD in 2008. Taking into account all above-mentioned and the calculated GDD it was found that in years unfavourable for maize growing, only early sowing can ensure adequate DM accumulation in maize yield. Average DM content in maize yield was significantly ($p < 0.05$) affected by the sowing date and decreased with every subsequent date: 277 g kg^{-1} if maize was sown on 25 April, 263 g kg^{-1} if maize was sown on 5 May, 255 g kg^{-1} if maize was sown on 15 May, and 240 g kg^{-1} if maize was sown on 25 May. More detailed DM content changes in fresh maize yield depending on the sowing date ($p < 0.05$) for every hybrid used ($p < 0.05$) and on each date of harvest ($p < 0.05$) are shown in Table 3. Also agro-climatic conditions in the trial year significantly ($p < 0.05$) influenced DM content, but the interaction "hybrid × sowing date" had no significant ($p > 0.05$) influence.

Table 3. Average DM content (g kg^{-1}) of four maize hybrids depending on the sowing date when harvested on four different dates

2005–2008, Vecauce

Hybrid	Sowing date	Harvesting date				Average per sowing date
		1 Sept.	10 Sept.	20 Sept.	1 Oct.	
'Earlystar' FAO 160	25 April, $LSD_{0.05}$ = 34	254^{a}	272^{ab}	303^{b}	350^{c}	**295***
	5 May, $LSD_{0.05}$ = 35	230^{a}	263^{ab}	289^{b}	325^{c}	**277**$^{\times}$
	15 May, $LSD_{0.05}$ = 31	220^{a}	252^{b}	270^{b}	331^{c}	**268**$^{\times o}$
	25 May, $LSD_{0.05}$ = 43	209^{a}	234^{ab}	272^{b}	319^{c}	**258** ^{o}
RM-20 FAO 180	25 April, $LSD_{0.05}$ = 34	235^{a}	263^{ab}	292^{b}	327^{c}	**279***
	5 May, $LSD_{0.05}$ = 35	226^{a}	250^{a}	286^{b}	316^{b}	**269**$^{*\times}$
	15 May, $LSD_{0.05}$ = 31	213^{a}	258^{b}	273^{b}	306^{c}	**262**$^{\times}$
	25 May, $LSD_{0.05}$ = 43	202^{a}	224^{ab}	258^{bc}	282^{c}	**241**^{o}
'Tango' FAO 210	25 April, $LSD_{0.05}$ = 34	243^{a}	273^{ab}	300^{b}	347^{c}	**291***
	5 May, $LSD_{0.05}$ = 35	231^{a}	254^{ab}	285^{b}	330^{c}	**275**$^{\times}$
	15 May, $LSD_{0.05}$ = 31	211^{a}	253^{b}	279^{b}	315^{c}	**265**$^{\times}$
	25 May, $LSD_{0.05}$ = 43	205^{a}	228^{ab}	264^{bc}	298^{c}	**249**^{o}
'Cefran' FAO 340	25 April, $LSD_{0.05}$ = 34	206^{a}	229^{ab}	247^{b}	283^{c}	**241***
	5 May, $LSD_{0.05}$ = 35	201^{a}	217^{ab}	241^{bc}	262^{c}	**230**$^{\times}$
	15 May, $LSD_{0.05}$ = 31	194^{a}	213^{ab}	231^{bc}	254^{c}	**223**$^{\times o}$
	25 May, $LSD_{0.05}$ = 43	181^{a}	205^{ab}	226^{b}	240^{b}	**213**^{o}

Notes. Different letters in superscript (^{a,b,c,d}) within the same row mark significantly ($p < 0.05$) different DM contents. Different symbols (*,$^{\times}$, ^{o}) for every hybrid mark significantly different ($p < 0.05$) average values per sowing date.

Plant height. Plant height is strongly related to genetic characteristics of the plant, and, besides, is influenced by meteorological conditions during plant growth and development. On average, the tallest maize plants ($p < 0.05$) were observed when maize was sown on the latest sowing date (25 May), but slightly taller plants – when sown on 5 May (Table 4).

A clear interpretation of the comparatively taller maize plants obtained in the-latest-date-sown plots was not found, but probably it was caused by interaction of environmental factors (temperature, moisture, light, availability of nutrients in specific development stages, etc.). Such assumption arises also from the findings of Berzsenyi et al. (1999, cited from Racz et al., 2003). Abdel Rahman et al. (2001) have found that maize plant height was affected by the sowing date, but in their trials taller plants were obtained in the plots sown both on the earliest and latest sowing date.

Despite the sowing date, only in the year 2006, with a very hot and dry growing season, plant height on average did not reach 2.00 m. Also the hybrid influenced the plant height substantially ($p < 0.05$). Hybrids can be ranked according to plant height (PH) in the same order as their maturity – earlier were the shortest regardless of the sowing date ('Earlystar', FAO 160, PH – 2.21 m; RM-20, FAO 180, PH – 2.31 m; 'Tango', FAO 210, PH – 2.42 m; 'Cefran', FAO 340, PH – 2.47 m; $p < 0.05$).

Table 4. Average maize plant height (m) of all hybrids depending on the sowing date and the trial year

Trial year	Sowing date				Average maize height in trial year
	25 April	5 May	15 May	25 May	
2005, $LSD_{0.05}$ = 0.06	2.58	2.57	2.55	2.75	2.61
2006, $LSD_{0.05}$ = 0.06	1.81	1.99	1.82	1.99	1.90
2007, $LSD_{0.05}$ = 0.05	2.33	2.38	2.25	2.57	2.38
2008, $LSD_{0.05}$ = 0.09	2.39	2.35	2.56	2.74	2.51
On average per sowing date $LSD_{0.05}$ = 0.03	2.28	2.32	2.29	2.51	×

Maize DM yield and quality. Although maize sown on 25 April had longer time to develop, it gave lower ($p < 0.05$) yield than that sown on 5 May (Table 5). This can be explained by the prolonged germination of seed under the cool weather conditions after such early sowing (for maize); the prolonged germination, in turn, can cause development of a bit weaker plants. This presumption is in agreement with other findings that the decreased soil temperature in the apex region significantly influences the overall performance of plant (Hund et al., 2008). In addition, plants sown on the 1st sowing date were slightly shorter and less in number per ha at harvest (see subsection *Development of maize* and Table 4). Although DM content of maize sown on 25 April in all cases was higher (Table 3) than that of the maize sown on later sowing dates, it could not compensate for the lower fresh maize yield. Also the yield of maize sown on the 3rd sowing date (15 May) was lower than that of maize sown on 5 May. It is possible that under other conditions the result of maize sown on 15 May might be better. In each research year some adverse conditions occurred directly influencing the sown plots, e.g., the year 2007 was very wet during the sowing time (12.8 mm of rain fell only in one day – 15 May) therefore seeds had to be placed in mud, and the experience shows that maize is susceptible to sowing in mud.

Table 5. Average DM yield (t ha^{-1}) of four maize hybrids on four different harvesting dates depending on the sowing date 2005–2008, Vecauce

Sowing date (B)	Harvesting date (C), $LSD_{0.05BC}$ = 1.17				On average per sowing date $LSD_{0.05B}$ = 0.58
	1 Sept.	10 Sept.	20 Sept.	1 Oct.	
25 April	11.20	13.16	14.14	15.37	**13.47**[a]
5 May	12.46	13.92	15.12	15.86	**14.34**[b]
15 May	11.41	13.27	13.56	14.87	**13.28**[a]
25 May	11.04	12.68	14.38	15.68	**13.44**[a]

Note. Different letters in superscript ([a, b]) mark significantly ($p < 0.05$) different average-per-sowing-date DM yields.

Researchers under other growing conditions also have found that later sown maize always yields less than that sown on earlier sowing dates regardless of whether maize is grown for grain or for silage (Olson, Sander; 1988; Lauer et al., 1999; Lauer, 2003; Racz et al., 2003; Crowley, 2005). Lauer et al. (1999) have concluded that an optimum maize sowing date exists for each specific location, and yield reduction is observed when sown before and after this date.

Keane (2002), just the opposite, has reported only one case when earlier sown maize gave higher yield; his research results on average per five years did not show any apparent relationship between sowing date and DM yield. Whereas Crowley (2005) in Ireland has found that use of a plastic film can equalize DM yield of early (10 April) and late (24 May) sown maize, especially in poor growing conditions. In Latvia, such experiments with use of a plastic cover have not been carried out yet, but such approach should be considered as besides its positive agronomic effect it may prove rather expensive.

The present research showed that average (per four hybrids, four years, four harvesting dates) DM yield of maize sown on 25 May was not significantly lower than that sown on 25 April and 15 May, which could be explained by taller plants (Table 4) and higher plant density at harvest (see subsection *Development of maize*). At the same time, quality of maize yield if sown on 25 May was much lower if compared with results obtained in earlier sown plots (Tables 3 and 7–8).

None of the hybrids, included in our research, was early enough to provide good yield on 1 September even if maize was sown on 25 April, and a substantial ($p < 0.05$) yield increase prevailed till 10 September (Table 6). The effect of sowing date on DM yield was significant ($p < 0.05$) each trial year, but it was more expressed in the years 2005 and 2007. Autumn frosts (17–18 September) stopped DM accumulation in 2005; therefore early sown maize gave higher yields that year. Whereas the good temperature and moisture conditions for maize growth and development in the first half (May and June, Table1) of 2007 ensured preference of early sown maize. In 2006, just the opposite, the first half of the season (Table 1) was overly hot and dry and heavy drought stress was observed; moreover, maize sown on 25 April and 5 May suffered from spring frosts on 1 June. In such conditions the influence of sowing date, even if substantial ($p < 0.05$), was less expressed and it was most important to harvest maize as late as possible. This agrees also with other findings that the impact of sowing date can depend on the conditions in the succeeding season (Lauer et al., 1999).

In general, it was beneficial to harvest maize in late September regardless of the hybrid and the sowing date (Gaile, 2010). Besides, it should be taken into account that earlier sown maize (25 April and 5 May) can be harvested already in the middle of September (Tables 3 and 6), which provides possibility of harvesting high enough, good-quality yield and avoiding late harvest risks (frosts, heavy autumn rains, mud in silo, etc.).

Table 6. Average DM yield (t ha^{-1}) of four maize hybrids depending on the sowing date when harvested on four different dates

2005–2008, Vecauce

Hybrid	Sowing date	Harvesting date				Average per sowing date
		1 Sept.	10 Sept.	20 Sept.	1 Oct.	
'Earlystar' FAO 160	25 April, $LSD_{0.05}$ = 1.37	12.53^{a}	13.96^{b}	14.58^{bc}	15.37^{c}	$14.11^{*\times}$
	5 May, $LSD_{0.05}$ = 1.46	12.09^{a}	14.03^{b}	15.65^{c}	15.26^{bc}	14.26^{*}
	15 May, $LSD_{0.05}$ = 1.09	10.92^{a}	13.09^{b}	13.54^{bc}	14.41^{c}	$12.99^{\times}$
	25 May, $LSD_{0.05}$ = 1.04	10.99^{a}	13.03^{b}	15.03^{c}	15.56^{c}	$13.65^{*\times}$
RM-20 FAO 180	25 April, $LSD_{0.05}$ = 1.24	10.78^{a}	12.00^{a}	13.49^{b}	15.62^{c}	12.97^{*}
	5 May, $LSD_{0.05}$ = 1.36	12.56^{a}	13.64^{ab}	14.78^{bc}	15.74^{c}	$14.18^{\times}$
	15 May, $LSD_{0.05}$ = 0.99	11.52^{a}	13.36^{b}	13.40^{b}	14.80^{c}	$13.27^{*\times}$
	25 May, $LSD_{0.05}$ = 0.92	10.93^{a}	12.52^{b}	14.13^{c}	15.28^{d}	$13.22^{*\times}$
'Tango' FAO 210	25 April, $LSD_{0.05}$ = 0.93	11.07^{a}	13.69^{b}	14.38^{bc}	15.14^{c}	$13.57^{*\times}$
	5 May, $LSD_{0.05}$ = 1.25	12.66^{a}	13.87^{ab}	15.09^{bc}	16.00^{c}	14.41^{*}
	15 May, $LSD_{0.05}$ = 1.15	10.95^{a}	13.34^{b}	13.46^{b}	14.75^{c}	$13.13^{\times}$
	25 May, $LSD_{0.05}$ = 0.90	11.26^{a}	12.34^{b}	14.02^{c}	16.30^{d}	$13.48^{*\times}$
'Cefran' FAO 340	25 April, $LSD_{0.05}$ = 1.28	10.43^{a}	12.99^{bc}	14.10^{cd}	15.34^{d}	13.21^{*}
	5 May, $LSD_{0.05}$ = 1.21	12.52^{a}	14.15^{b}	14.94^{b}	16.45^{c}	$14.51^{\times}$
	15 May, $LSD_{0.05}$ = 1.08	12.26^{a}	13.29^{ab}	13.83^{b}	15.51^{c}	$13.72^{*\times}$
	25 May, $LSD_{0.05}$ = 1.01	10.96^{a}	12.82^{b}	14.32^{c}	15.56^{d}	$13.42^{*\times}$

Notes. Different letters in superscript ($^{a,\ b,\ c,\ d}$) within the same row mark significantly ($p < 0.05$) different DM yields. Different symbols (*,$^{\times}$, ^{o}) for every hybrid mark significantly different ($p < 0.05$) average values per sowing date.

Preliminary maize quality indicators which show that silage of good nutritional value can be made are DM content in fresh maize at harvest (analysed in subsection *Development of maize*), and content of ears in the total maize DM yield. Ear proportion allows us to judge about grain content in maize yield, but grain is the main energy source in maize silage harvested at dough-dent stage. Less grain yield usually lowers the silage quality (Lauer, 2003). In our research, sowing date significantly influenced the average (from four years, four hybrids, four harvest dates) proportion of ears: 495 g kg^{-1} if maize was sown on 25 April, almost equal, 467 and 466 g kg^{-1}, if sown on 5 and 15 May, respectively, and 396 g kg^{-1} if sown on 25 May ($LSD_{0.05}$ = 17). This is in conformity with data of Keane (2002) who has found a significant ear proportion decrease if maize was sown on later dates. Also Lauer (2003) has reported that later sowing affected grain yield to a greater extent if compared with stover yield, therefore the grain/stover ratio decreased with later planting mainly due to lower grain yield. Cirilo and Andrade (1996) have found that delayed sowing of maize caused decrease in grain number and kernel weight. Whereas in our research, delayed sowing might have resulted in a lower proportion of ear DM yield in the whole maize plant DM yield.

Analysis of the results of a particular hybrid showed that ear proportion close to 500 g kg^{-1} was reached on 10–20 September if earlier maturity hybrids (FAO 160–210: 'Earlystar', RM-20, 'Tango') were sown on the first three sowing dates (25 April till 15 May). If sown on 25 May, then only at the end of September such ear proportion can be obtained. Latest hybrid 'Cefran' (FAO 340), sown on 25 April and 5 May and harvested on 1 October, reached ear proportion slightly above 500 g kg^{-1} (Table 7).

Thus, analysing data of DM yield, content of DM and proportion of ears in the whole plant DM yield it can be concluded that sowing of early maturity maize (in this research – FAO up to 210) in the 1^{st} ten-day period of May or in early 2^{nd} ten-day period of May can give the best DM yield with proper preliminary quality when harvested in the second half of September. If overly late maturity hybrids ('Cefran', FAO 340) are used, sowing should be done on last days of April or in early May, and harvesting – as late as possible. Such situation is possible if maize is used for biogas production, for which later maturity hybrids are advised in order to obtain higher yield (Bartuševics, Gaile, 2009). This finding is in agreement with the conclusions in the literature (Lauer et al., 1999; Racz et al., 2003) that early and ultra-early hybrids can be sown a bit later than full season or late maturity hybrids.

Later sowing of maize caused some decrease in the average maize nutrition quality – values of NDF (neutral detergent fibre), ADF (acid detergent fibre), and NEL (net energy for lactation) increased, which can be explained by harvesting slightly less matured maize (Table 8).

Table 7. Average proportion of ear DM yield (g kg^{-1}) in the total maize DM yield of four maize hybrids depending on the sowing date when harvested at four different dates
2005–2008, Vecauce

Hybrid	Sowing date	Harvesting date				Average per sowing date
		1 Sept.	10 Sept.	20 Sept.	1 Oct.	
‘Earlystar’ FAO 160	25 April, $LSD_{0.05}$ = 20	425^{a}	501^{b}	567^{c}	607^{d}	**525*****
	5 May, $LSD_{0.05}$ = 24	399^{a}	460^{b}	525^{c}	590^{d}	**494***
	15 May, $LSD_{0.05}$ = 24	378^{a}	498^{b}	563^{c}	605^{d}	**511***
	25 May, $LSD_{0.05}$ = 19	298^{a}	392^{b}	499^{c}	582^{d}	**443$^{×}$**
RM-20 FAO 180	25 April, $LSD_{0.05}$ = 19	424^{a}	481^{b}	555^{c}	597^{d}	**514***
	5 May, $LSD_{0.05}$ = 21	376^{a}	440^{b}	512^{c}	579^{d}	**477$^{×}$**
	15 May, $LSD_{0.05}$ = 18	360^{a}	471^{b}	529^{c}	579^{d}	**485*$^{×}$**
	25 May, $LSD_{0.05}$= 17	288^{a}	369^{b}	445^{c}	518^{d}	**405^{o}**
‘Tango’ FAO 210	25 April, $LSD_{0.05}$ = 22	481^{a}	517^{b}	568^{c}	595^{d}	**540***
	5 May, $LSD_{0.05}$ = 19	457^{a}	495^{b}	561^{c}	577^{c}	**523***
	15 May, $LSD_{0.05}$ = 17	407^{a}	493^{b}	551^{c}	607^{d}	**514***
	25 May, $LSD_{0.05}$ = 18	347^{a}	413^{b}	523^{c}	557^{d}	**460$^{×}$**
‘Cefran’ FAO 340	25 April, $LSD_{0.05}$ = 15	287^{a}	348^{b}	446^{c}	524^{d}	**401***
	5 May, $LSD_{0.05}$ = 15	246^{a}	320^{b}	424^{c}	513^{d}	**375*$^{×}$**
	15 May, $LSD_{0.05}$ = 16	218^{a}	301^{b}	402^{c}	487^{d}	**352$^{×}$**
	25 May, $LSD_{0.05}$ = 15	156^{a}	232^{b}	317^{c}	404^{d}	**277^{o}**

Notes. Different letters in superscript ($^{a, b, c, d}$) within the same row mark significantly (p < 0.05) different ear DM yield proportion. Different symbols (*,$^{×}$, ^{o}) for every hybrid mark significantly different (p < 0.05) average values per sowing date.

Table 8. Average NDF and ADF (g kg^{-1}) content, and NEL (MJ kg^{-1} DM) depending on the sowing date
2005–2008, Vecauce

Maize quality parameter	Sowing date			
	25 April	5 May	15 May	25 May
NDF	500^{a}	506^{ab}	510^{b}	518^{c}
ADF	256^{a}	262^{b}	267^{b}	275^{c}
NEL	6.57^{a}	6.52^{b}	6.48^{b}	6.42^{c}

Note. Different letters in superscript ($^{a, b, c}$) within the same row mark significantly (p < 0.05) different values of quality parameters.

Although the influence of sowing time on CP content was mathematically significant (p < 0.05), from the agronomic point of view it was still unimportant, because the great average of CP from all years, hybrids, sowing and harvesting dates was 72 g kg^{-1}. It is well known that maize is not a rich source of protein; in addition, CP content is more affected by the harvesting date (Gaile, 2010).

Conclusions

1. Sowing date significantly influenced maize development from germination till harvesting. Maize needed on average 49 growing degree days (GDD) from sowing till emergence, 463–518 (depending on the hybrid) GDD from emergence till silking, but from silking till maturity stage when 250 g kg^{-1} of dry matter (DM) content in fresh maize was achieved – 257 GDD. A strong negative (p < 0.05) correlation between the soil temperature at 10-cm depth and the number of days from maize sowing till full emergence was noted. Earlier sown maize needed more days till germination (18–8 days) and from germination till silking (79–67), whereas the period after silking till maturity stage, when 250 g of DM kg^{-1} of fresh maize were reached, was 40–47 days depending on the hybrid but regardless of the sowing date. Plants sown on the last sowing date (25 May) were significantly taller and plant density was higher (p < 0.05) if compared with earlier sown maize.

2. The best and significantly higher average DM yield was obtained when maize was sown on 5 May; however, depending on the conditions in a particular year and on the hybrid, maize sown on 25 April and 15 May showed good results, but maize performance depended on the year, the hybrid, and on the evaluated parameter. Although sowing on 25 May can also ensure a high yield of maize DM, the DM content and ear proportion in the whole plant DM yield was sharply decreased.

3. The best average values of any evaluated quality parameter – DM content, ear proportion in the whole plant DM yield, neutral detergent fibre (NDF), acid detergent fibre (ADF), energy for lactation (NEL), and crude protein (CP) – were obtained when maize was sown on 25 April. A greater effect of sowing date on the yield and quality was observed in the years when growth and de-

velopment of plants proceeded normally (2007) or when autumn frosts occurred earlier in September (2005).

4. The main conclusion is that the most favourable time to sow maize in Southwest of Latvia is around 5 May. If later sowing dates are chosen, only very early maturity hybrids should be used. If growers use later (compared to traditionally grown) maize hybrids (e.g., for biogas production) they are advised to consider sowing in the last days of April.

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Paprastojo kukurūzo (*Zea mays* L.) reakcija į sėjos laiką Latvijos agroklimato sąlygomis

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Santrauka

Paprastasis kukurūzas (*Zea mays* L.) yra gana naujas lauko augalas Latvijoje (ekstensyviai auginamas tik nuo 1954 m.). Auginimo nesėkmės dėl nepalankių oro sąlygų dažniausiai išryškėja taikant netinkamas technologijas. Sėjos laiko svarba yra plačiai tyrinėta daugelyje šalių ir nustatyta, kad ankstyva sėja specifinėms sąlygoms duoda didesnį derlių.

Tyrimas atliktas 2005–2008 m. Latvijos žemės ūkio universiteto Vecauce bandymų ūkyje, Latvijos pietvakarinėje dalyje, siekiant patikslinti kukurūzų sėjos laiką ir ištirti jų augimą, priklausomai nuo sėjos laiko. Tirti keturi kukurūzų hibridai – 'Earlystar', RM-20, 'Tango' ir 'Cefran', pasėti keturiais skirtingais laikais – balandžio 25, gegužės 5, 15 ir 25 dienomis, *Luvic Epigleyic Phazeozem* (*Calcaric*), lvPH (glp:ca) dirvožemyje. Kukurūzai pjauti irgi keturiais skirtingais laikais, pradedant nuo rugsėjo 1 d., kas dešimt dienų. Tyrimo rezultatai parodė, kad anksčiau pasėtiems kukurūzams reikėjo daugiau dienų iki sudygimo ir nuo sudygimo iki šilko tarpsnio. Dienų skaičius nuo šilko tarpsnio iki brandos, kai buvo pasiektas 250 g kg^{-1} sausųjų medžiagų (SM) kiekis, priklausė nuo kukurūzo hibrido, bet ne nuo sėjos laiko. Sukauptų efektyvių temperatūrų suma, reikalinga tam tikram tarpsniui pasiekti, nuo sėjos laiko nepriklausė ($p > 0.05$). Augalai buvo aukštesni ir jų tankis buvo didesnis, pasėjus vėlai (gegužės 25 d.). Geriausias ir esmingai ($p < 0.05$) didesnis vidutinis SM derlius (14,34 t ha^{-1}) gautas kukurūzus pasėjus gegužės 5 d. Vidutinis derlius buvo mažesnis, bet panašus (13.28–13.47 t ha^{-1}) kukurūzus pasėjus ir anksčiau ar vėliau. Sėjos laikas turėjo nedidelę, bet esminę ($p < 0.05$) įtaką SM, žalių baltymų, NDF bei ADF kiekiui, NEL ir burbuolių kiekiui suminiame SM derliuje. Kukurūzus pasėjus anksčiau, gauti geresni rezultatai. Geriausias kukurūzų sėjos laikas Latvijos centrinėje ir vakarinėje dalyse yra maždaug gegužės 5 d. Kukurūzų vėlyvus hibridus reikėtų sėti balandžio paskutinėmis dienomis.

Reikšminiai žodžiai: *Zea mays*, sėjos laikas, meteorologinės sąlygos, hibridai, derlius, kokybė.