Effect of Soil Temperature at Different Planting Dates, and of Residue Management on Soybean

Project duration - 2014 – 2018

Objectives - A better understanding of the impact of management practices, including planting date and residue management practices, and of early-season soil temperatures, on soybean growth, yield and quality in Manitoba may help to refine management practices in order to reduce risks associated with cold temperatures and thereby to optimize soybean production. The objectives of this study were:

1. Experiment 1: to determine the effect of soil temperature at different planting dates on soybean growth, yield and quality
2. Experiment 2: to determine the effect of residue management on soybean growth, yield and quality

Collaborators - Manitoba Pule & Soybean Growers
Ramona Mohr – Research Scientist, AAFC
Craig Linde – Diversification Specialist, Manitoba Agriculture
James Frey – Diversification Specialist, Manitoba Agriculture

Results

Results of the current study suggest that delaying planting beyond the currently recommended planting window of May 15th to 25th has the potential to result in significant yield penalties and may present a significant production risk. Under the conditions of this study, delayed planting resulted in marked yield declines in most site-years at Brandon, Carberry and Portage (Figure 1). Delaying planting in this study, typically by 9 to 15 days (from the 3rd to 4th week of May into June), resulted in 40 to 80% the yield of the May planting dates depending upon the site-year. Further, at one of three years at Roblin, significant frost damage occurred with the later planting date resulting in negligible yields.

A strong and clear relationship between soil temperature at planting and soybean performance was not evident under the conditions of the current study. In Study 1, soil coverings installed in the field in early spring often produced a range of soil temperatures at planting, and for varying lengths of time thereafter, but differences in soil temperature at planting were not consistently associated with differences in soybean yield (Figure 1). This was the case although soil temperatures at planting were often below the 18 to 22 °C suggested as ideal based on current provincial recommendations, and occasionally <10 °C. Of five cases where yields were higher in “warm” treatments that had been covered by black plastic than in “cold” treatments covered by Styrofoam, warmer temperatures at planting were evident in the “warm” treatments in only three cases.

Similar general trends were evident in Study 2, which assessed the effect of residue management practices preceding soybean on soil temperature and its relationship to soybean performance. Although residue management frequently influenced early-season soil temperature and/or moisture, and occasionally affected the days to crop emergence, effects on soybean yield were limited (2 of 12 site-years) (Figure 2). In part, because soybeans had been planted within the recommended planting dates for Manitoba and when soil temperatures exceeded the critical 10 °C, the effects of residue management on growth and yield may have been less than under more marginal conditions.

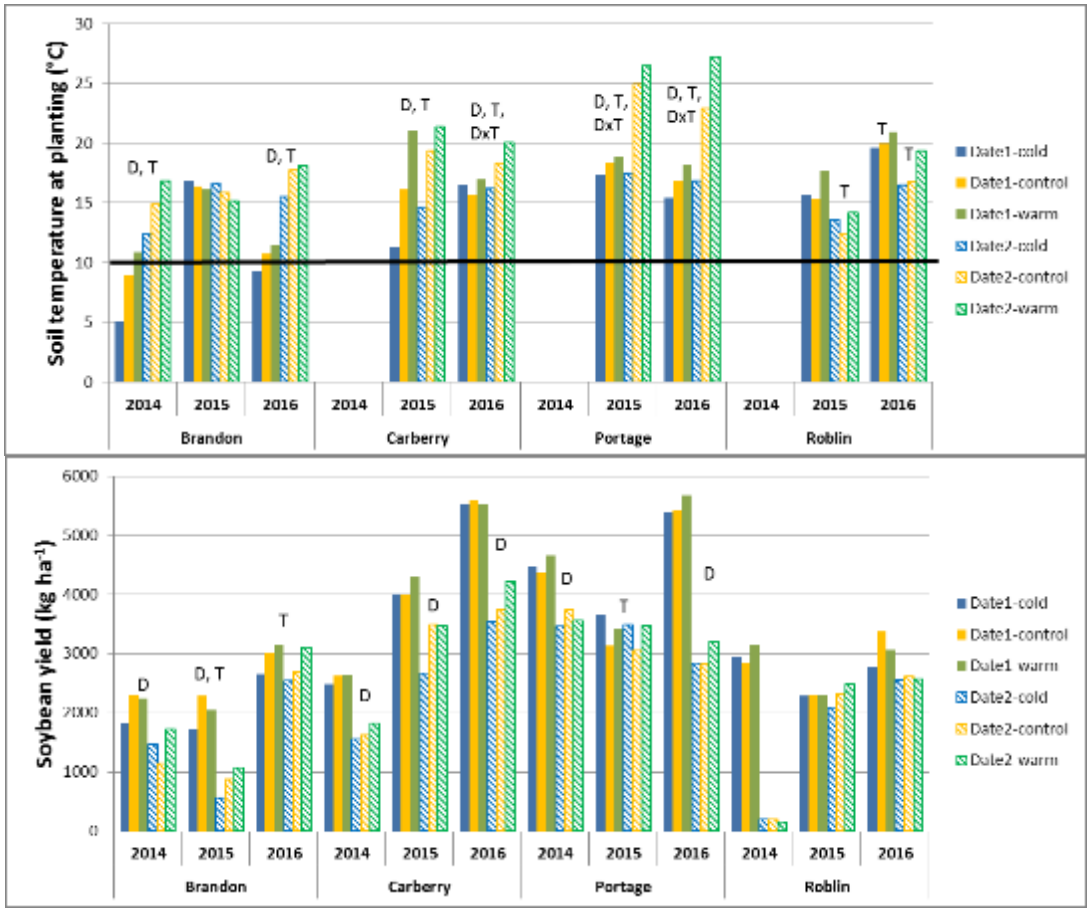

Figure 1. Effect of planting date and soil temperature treatment on soil temperature measured at time of planting and on soybean yield at Brandon, Carberry, Portage and Roblin (2014-16). (D, T and DxT indicate significant (P≤0.05) effects of planting date (D), temperature treatment (T), and DxT interactions based on analysis of variance.)

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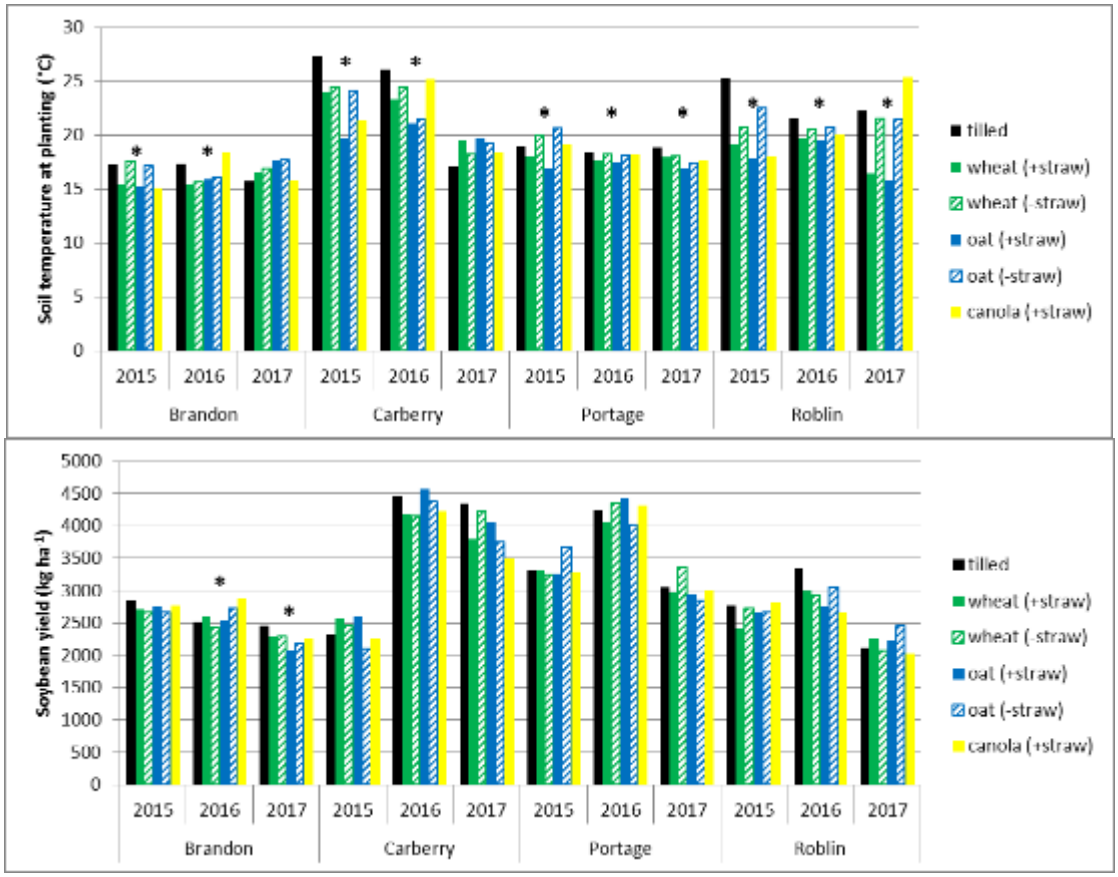

Figure 2. Effect of residue management practices on soil temperature measured at time of planting and on soybean yield at Brandon, Carberry, Portage and Roblin (2015-17). (indicates a significant (P≤0.05) effect of residue management treatment based on analysis of variance by site-year.)*

In conclusion, managing the risk of cold temperature damage in soybean crops grown in short-season areas can be most effectively addressed with an integrated approach. Selection of a well-adapted cultivar suited to local growing conditions is key, as are appropriate planting dates and soil temperature conditions. Current provincial recommendations suggest that soybean be planted from May 15th to May 25th, or when the average soil temperature has reached 10 °C, with 18 to 22 °C considered ideal (Manitoba Agriculture 2013). These research findings suggest that delaying planting beyond the recommended window may result in a significant yield penalty and may expose the crop to fall frost damage. The relationship between soil temperature at planting and soybean growth and yield appears to be more complex, however. The potentially damaging effects of chilling injury, which occurs when soybean seed imbibes water of <10 °C particularly during the first 24 hours after planting, is well-recognized, and underlies the recommendation to delay seeding until the average soil temperature has reached 10 °C. However, the current study did not identify a clear relationship between soil temperature at planting and soybean establishment or yield when soil temperatures were >10 °C. While the current research findings suggest that warmer temperatures at planting may occasionally enhance emergence and increase seed yield when soil temperatures at planting are >10 °C, warmer soil temperatures at planting did not consistently enhance crop emergence or translate into higher yields. When soybeans were planted within or near the recommended planting date

window and soil temperatures at planting were above the critical 10 °C, residue management practices like tillage and straw removal that often increased soil temperature to varying degrees (<1 to 5 °C) rarely increased seed yield. In order to better understand the effects of residue management practices on soybean growth and yield under a broader range of conditions, a field study was initiated in fall 2017 which will look at the effect of a range of residue management practices including burning, tillage, stubble height and straw removal on soybean planted before and during the recommended planting date window

Background

The Canadian prairies represent the northern fringe of soybean production in North America. Growing soybean in this region was long considered unlikely because few areas had more than 120 consecutive frost-free days, and temperatures during the frost-free period were too cold for adequate crop development (Burnett et al. 1985).

With the introduction of early-maturing cultivars adapted to Manitoba conditions, the soybean industry in this province has grown rapidly over the past decade. Production has expanded from traditional areas in the Red River Valley to other regions, leading to a record soybean acreage of 2.3 million acres in 2017 (Statistics Canada 2017).

Despite ongoing improvements to soybean cultivars, the short growing season and climate in Manitoba can be a significant production risk for this long-season crop. Frost and near-freezing conditions in spring and fall can damage soybean. Early planting in cool and wet conditions can increase seedling disease and reduce plant stand (NDSU Extension Service 2010). Soil temperature at seeding, together with soil moisture conditions, may impact establishment (Helms et al. 1996a; Helms et al. 1996b; Wuebker et al. 2001).

Potential may exist to reduce the risks associated with cool temperatures, frost and/or near-freezing conditions through management. Selection of well-adapted cultivars suited to short-season areas is critical. However, proper choice of planting date, and management of preceding crop residue, may influence early-season temperatures and therefore crop growth.

A better understanding of the impact of these factors on soybean growth, yield and quality in various regions within Manitoba may help to refine management practices in order to reduce production risk and optimize soybean production.

Planting date: Manitoba recommendations indicate that soybean should be planted from May 15th to May 25th, or when the average soil temperature has reached 10°C, with 18 to 22°C considered ideal (Manitoba Agriculture 2013). North Dakota recommendations suggest that soybeans not be planted earlier than five days before the average date for the last killing frost in order to reduce the risk of spring frost damage (NDSU Extension Service 2010).

Manitoba production data indicates that soybean yield generally decreases with delayed seeding (Manitoba Agricultural Services Corporation 2013), although research suggests this effect may vary among regions in Manitoba. In seeding date trials in the Morden/Carman area conducted from 2006 through 2008, yield was similar for May planting dates but declined with mid-June planting dates (Manitoba Agriculture 2011). At Arborg, yield declined when planting was delayed until late May and declined further when planting was delayed until mid-June. Soil temperature at planting may have influenced the results obtained. As well, because a killing frost did not occur until late September in these studies, yield differences among planting dates were likely smaller than if an early fall frost had occurred.

In studies conducted in North Dakota, early planting of late-maturing cultivars (Maturity Group I and II) did not increase yield, but early planting of early-maturing cultivars (Maturity Group 0) that were adapted to the region increased yield when an early fall frost occurred (Halvorson et al. 1995). Although early planting increased the risk of spring frost damage, this approach allowed the option of re-planting.

Effect of residue management: Soybean may be grown under a range of cultural practices, from conventional to reduced tillage systems (NDSU Extension Service 2010). Residue management practices may influence the micro-environment the crop is exposed to, both above and below the soil surface. In field studies near Brandon, MB, the effect of wheat residue management (short stubble, tall stubble, cultivated) on canola, pea and wheat was assessed from 2000-02 (Volkmar and Irvine 2003). In this study, stubble delayed day-time soil warming and night-time cooling at the soil surface and at a depth of 7.5 cm, and generally increased day-time and decreased night-time air temperature compared to the cultivated treatment. Stubble treatments also typically had higher soil moisture levels than the cultivated soil. Although these micro-environment effects contributed to increased emergence and vegetative growth, especially for tall stubble, there was minimal effect on crop yield. Little information is available regarding the effect of stubble management on soybean in Manitoba.

Another aspect of residue management that could potentially affect crop growth relates to the type of residue. Anecdotal information suggest that, in the case of canola, direct seeding into oat stubble may sometimes slow emergence and increase the risk of frost damage compared to other cereal stubble types. This effect has been attributed to the “brightness” of the oat straw relative to other cereals, which may reflect more incident light and result in cooler soil and air temperatures near the soil surface. This effect has not been documented in Manitoba however.

Materials & Methods

A series of field studies were conducted at each of Brandon, Carberry, Portage and Roblin during the period 2014 through 2017 as outlined below. Two experiments were conducted at each site over three field seasons: Experiment 1: Effect of soil temperature at different planting dates on soybean growth, yield and quality (2014-16) and Experiment 2: Effect of residue management on soybean growth, yield and quality (2015-17).

Experimental design and management

Experiment 1. Effect of soil temperature at different planting dates on soybean growth, yield and quality

Small plot field experiments were conducted at four Manitoba sites (Brandon, Carberry, Portage, Roblin) in each of 2014 through 2016. Details regarding the experimental sites are summarized in Table 1. A randomized complete block design (RCBD) with four replicates was established, with treatments arranged in a split plot design consisting of two planting dates (main plots) and three soil temperature treatments (subplots). At Roblin only, main plots were not randomized due to logistical factors; therefore early and late planting dates were considered as two separate studies for the purpose of analysis.

Planting dates consisted of an earlier and later planting date, with the earlier planting date typically occurring from mid- to late May, and the later planting date typically 9 to 15 days later. Three soil temperature treatments, designated as “cold”, “control” and “warm” depending upon the soil coverings applied, were established as subplots. To produce soil temperature treatments, plots were covered in early spring with: 1) styrofoam and/or reflective material to insulate the soil (“cold”); 2) black plastic to warm the soil (“warm”); and 3) white+clear plastic to reflect the sun (“control”) (Figure 1).

Soil coverings were typically removed shortly before seeding to allow some drying of the soil surface prior to seeding, while maintaining soil temperature differences. Soybean (RR2, Maturity grouping 00.1, short-season zone) commercially treated with seed treatment and Rhizobium was solid-seeded directly into untilled soil at a rate of 50 pure live seeds per m2. The germination rate of the seed lots used ranged among years from 97 to 100%. Soybeans

were grown using generally-accepted agronomic practices with respect to seeding, fertilizer, weed, and harvest management.

Experiment 2. Effect of residue management on soybean growth, yield and quality

Small plot field studies were initiated at four Manitoba sites (Brandon, Carberry, Portage, Roblin) in 2014. Residue management treatments were imposed at each site in 2014, 2015 and 2016, with soybean established into these treatments in each of 2015, 2016 and 2017. A randomized complete block design (RCBD) with four replicates was established, comprised of six residue management treatments: control (wheat residue, fall tilled), wheat with straw chopped and retained (standing stubble), wheat with straw removed (standing stubble), oat with straw chopped and retained (standing stubble), oat with straw removed (standing stubble), and canola with straw chopped and retained (standing stubble).

During the year of stubble establishment, hard red spring wheat, oat, and hybrid canola were established at each site using the same seed lot, with seeding rates adjusted to achieve 250, 300 and 120 plant m-2, respectively. Generally-accepted agronomic practices with respect to seeding, fertilizer, weed, and harvest management were applied. In most site-years, residue management treatments were imposed in the fall prior to soybean as per treatment. Exceptions were Roblin where tillage treatments were conducted in the spring prior to soybean establishment, and Brandon in 2014 where the fall tillage treatment was delayed until spring.

Soybean (RR2, Maturity grouping 00.1, short-season zone) commercially treated with seed treatment and Rhizobium was solid-seeded at a rate adjusted to achieve 40 plants per m^2. The same cultivar and seed lots were used in Experiments 1 and 2. Soybeans were grown using generally-accepted agronomic practices with respect to seeding, fertilizer, weed, and harvest management.

Data collection and analysis (Experiments 1 and 2)

Similar datasets were collected from Experiments 1 and 2. Soil temperatures were recorded hourly using self-logging sensors (Model DS1922L, iButton Temperature Logger, Maxim Integrated) installed at a 5 cm depth in each plot following planting at two sites in 2014 (Brandon and Carberry) and all four sites in 2015 and 2016 for Experiment 1. In Experiment 2, two iButton loggers were installed in each plot at a 5 cm depth. One logger was installed at the front and back of each plot, approximately 1 m from the plot edge.

In both experiments, soil temperature and moisture were also measured at seeding depth at time of planting using a manual digital thermometer (Key-Chain Thermometer, Fisher Scientific) and soil moisture probe (ML3 ThetaProbe, Delta-T Devices). Plant counts were conducted periodically for several weeks after planting, from the first evidence of crop emergence until no further change in plant stand was detected. At crop maturity, plots were harvested by plot combine and cleaned yields determined. Test weight, % oil and % protein of seed was determined using an Infratec™ 1241 Grain Analyzer (Foss North America Inc., Eden Prairie, MN), and thousand seed weight determined using a mechanized seed counter. Date of emergence and crop growth stage were determined based on periodic visual assessment of the field experiments.

Both early-season biomass and Greenseeker measurements were collected in an effort to quantify early-season growth, in addition to the repeated plant counts conducted. Early-season biomass was determined by hand-harvesting 2-1 m lengths of row several weeks after planting and determining dry weight. Preliminary analysis of the early-season biomass data demonstrated a high degree of variability in most site-years which limited the value of this measurement for identifying treatment effects; therefore, these data have not been included in

the current report. Greenseeker measurements were collected using a handheld Greenseeker device periodically during the early part of the growing season; however, the presence of volunteers and/or weeds in some site-years influenced the readings obtained and therefore these data have not been included in the current report.

For the purpose of this report, data from each experiment were analyzed by site-year. For Experiment 1, data were analyzed as a split plot using Proc Mixed in SAS, with treatments considered fixed effects and replicates considered random effects. Data collected at Roblin were analyzed as a randomized complete block design separately for each planting date because planting date treatments had not randomized at this site for logistical reasons. For Experiment 2, data were analyzed as a randomized complete block design using Proc Mixed in SAS, with treatments and replicates considered fixed and random effects, respectively. A combination of Tukey's test and contrast analysis were used to identify treatment effects of interest. A P-value ≤0.05 was considered significant.

Sub-daily soil temperature (TSOIL) treatment means were calculated from the self-logging sensor data based on the 3-hour average values for each plot (i.e. n = 8 for TSOIL for every plot each day). Only those site-years where the sensors were installed the same day as planting and where data was retrievable from at least 3 out of 4 treatment replications were retained for further analyses from each experiment. Cumulative soil degree hours less than 10°C (∑SDH < 10°C) were calculated as the summation of negative values of TSOIL-10°C, and cumulative soil degree hours greater than 10°C (∑SDH > 10°C) were calculated as the summation of positive values of TSOIL-10°C . Preliminary statistical analyses of the TSOIL data indicated several interactions between year and site (Experiment 1 and Experiment 2), as well as site and planting dates within years (Experiment 1), so analyses focused in on each planting date separately for individual site-years to evaluate the significance of the temperature (Experiment 1) and residue (Experiment 2) treatments imposed for the studies. Sub-daily TSOIL data were analyzed for Experiment 1 for each site-year planting date with a univariate repeated-measures analysis of variance (ANOVA) model where plot (i.e. replicate) was considered a random effect, and treatment, days after planting (DAP) and the interaction term (treatment x DAP) were considered fixed effects using JMP software (version 13, SAS Institute, Inc.). The significance of the temperature (Experiment 1) and residue (Experiment 2) treatments imposed on ∑SDH < 10°C for 20 DAP and ∑SDH > 10°C for 30 DAP were tested using one-way ANOVA in SigmaPlot (version 13, Systat Software, Inc.). Where data did not meet the assumptions for parametric ANOVA (i.e. distribution not normal and/or unequal variances), the equivalent non-parametric statistical test was used (i.e. Kruskal-Wallis one-way ANOVA on ranks).