Stubble Effects on Crop Microclimate and Crop Performance in a Sub-humid Prairie Climate

K.M. Volkmar and B. Irvine

Brandon Research Centre, PO Box 1000a, RR#3, Brandon, Manitoba, R7A 5Y3. Email: kvolkmar@agr.gc.ca

Key Words: canola, crop residue, microclimate, pea, stubble, wheat

Abstract

Stubble impacts crop microclimate in ways that have not been well-investigated, particularly in the context of crop establishment, growth and yield. In this study, the effects of different stubble heights on crop microclimate, biomass accumulation, and yield were investigated in the black soil , sub-humid climate of southwest Manitoba. Canola, pea, and wheat were sown across stubble treatments, comprised of cultivated wheat stubble, or stubble cut to a height of 10 or 30 cm in the spring of the cropping year. Plots were instrumented to monitor soil and canopy air temperature, near-surface soil moisture, wind speed, and reflected solar radiation during crop establishment. Results are discussed in the context of how changes in crop microclimate induced by stubble treatment affected crop performance. Tall stubble delayed day-time soil warming and night-time cooling, increased day-time canopy air temperature and decreased night-time air temperature, increased surface and sub-surface soil moisture, reduced wind speed near the soil surface, and increased crop canopy reflectance. These micro-climatic effects increased seedling emergence, vegetative biomass, but had minimal impact on final crop yield. The results suggest that maintenance of tall stubble should not result in a yield penalty, and may reduce input costs through reduced energy required in combining.

Introduction

Cereals are routinely combined to a height of between 10 and 15 cm, which if left undisturbed, creates a protective cover of standing stubble that helps trap snow, and reduces the risk of soil erosion. The presence of crop stubble alters the micro-environment both above and below the soil surface. This altered microclimate may significantly impact crop establishment and growth of the crop sown the subsequent spring. The extent to which standing stubble influences crop establishment and yield is not well understood in the sub-humid region of the eastern prairies.

Past research has shown that tall stubble (35 cm or taller) increases crop yield and water use efficiency in semi-arid climate (Campbell et al. 1992; Cutforth and McConkey 1997). Based on their results, the authors recommended that producers in the semiarid prairies seed spring wheat directly into stubble left standing as tall as practical (at least 30 cm).

Because the benefit of tall stubble to yield under comparatively arid conditions was at least partly due to improved in-season moisture conservation, it raises the question as to whether similar benefits of tall stubble would be observed under conditions where soil moisture is less yield limiting. In the Melfort, SK area, crop yields varied by crop and by year in response to tall stubble but were generally comparable to those sown into cultivated stubble (Moulin et al. 1998), Further work is necessary to determine the merits of tall stubble technologies in higher rainfall regions of the prairies.

The purpose of this study was to determine the effect of stubble height on crop microclimate, and its subsequent effect on crop establishment, growth and yield in a sub-humid climate in western Manitoba.

Methodology

The study was carried out during 2000 - 2002 on a Newdale Clay Loam soil at a different site each year, approximately 25 km NE of Brandon. In the fall of 1999, 2000, and 2000, experimental sites were installed on on fields sown to wheat that had been previously combined leaving most of the wheat straw upright and intact (tall stubble) (1999, 40 cm; 2000, 45 cm; 2001, 50 cm). The following spring, stubble height treatments were imposed as soon as the ground was dry enough to drive on. The stubble treatments were as follows: stubble cut to 40 - 50 cm (tall) , stubble cut to 15 cm (short), and 15 cm stubble receiving one pass with a cultivator to a depth of 8 - 15 cm (cultivated). The cut straw remaining in creating the short and cultivated treatments was removed. The experimental design was a randomized complete block, replicated four times. Plot size was 30 m x 30 m. Plots were sown to wheat (AC Barrie), Canola (Liberty link - hybrid 2273), and field pea (Carnival) on May 16, 2000, May 22, 2001, and May 17, 2002, using a no-till disc drill with an 18-cm row spacing. All plots were sprayed with post-emergent herbicide for weed control. Fertilizer was mid-row banded at seeding (N) and seed-placed (P) at rates in accordance with general recommendations.

Microclimate measurements were made on two randomly-selected blocks at pre-planned locations. Air temperature (surface, 15, 50, 150 and 200 cm), soil temperature (7.5, 15, and 30 cm), soil moisture (5, 15, 30 45, 60, 90 cm), solar irradiance, relative humidity (25 & 200 cm), wind speed.(25 & 200 cm), and crop reflectance (450 - 950 nm). Air temperature was monitored at the soil/air interface, 15, 50, 100, and 200 cm using copper constantan thermocouples shielded and passively ventilated. Soil temperature was recorded at 7.5, 15, and 30 cm using Hobo sensors (Hoskins Scientific, Vancouver, BC). Wind speed was measured at 25 and 200 cm using Gill 3 Cup anemometers. Relative humidity probes with RM Young radiation shield were positioned at 25 cm until canopy was 50 cm tall, then adjusted to 50 cm thereafter. Rainfall was recorded using a tipping bucket rain gauge. Micro-meteorological measurements were recorded hourly using CR10 data loggers (Campbell Scientific, Canada). Soil moisture was measured gravimetrically prior to planting and after crop harvest to a depth of 100 cm from 5.0 cm diameter soil cores. Neutron attenuation was used to measure soil water content to 95 cm approximately every 10 days after planting. Pre-determined soil bulk densities were used to express water content on a volumetric basis.

Plant emergence was determined on two dates from four 1 m row lengths per plot. Yields were determined using a plot combine. Plant growth was assessed at selected dates from seeding to crop maturity from 2 2-m row lengths. In-season measurements were made on plant height, total shoot biomass and leaf area. In this paper we report on stubble height effects on micro-meteorological trends including soil and air temperature, soil moisture, and wind speed. The effects of these micro-climate effects on crop emergence, mid-season biomass, and on crop yield are presented.

Results

Micro-climate

Soil temperature

Stubble delayed early night time cooling and day time warming at the soil surface early in the growing season (Figures 1). On a twenty-four hour interval, tall stubble treatments were about 10 ^{0}C warmer than cultivated treatments, while short stubble treatments were about 2 degrees cooler than the cultivated treatments (Fig. 2). During this same period both short and tall stubble caused sub-surface (7.5 cm) soils to be cooler than cultivated soils (Fig. 3). At 30 cm, treatment differences were negligible, and did not vary diurnally (Fig. 4).

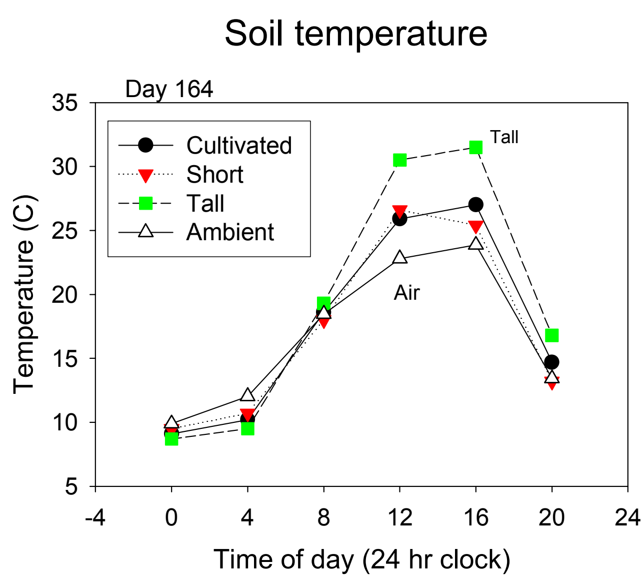


Figure 1. Mean daily surface soil temperature at emergence in response to stubble treatment.

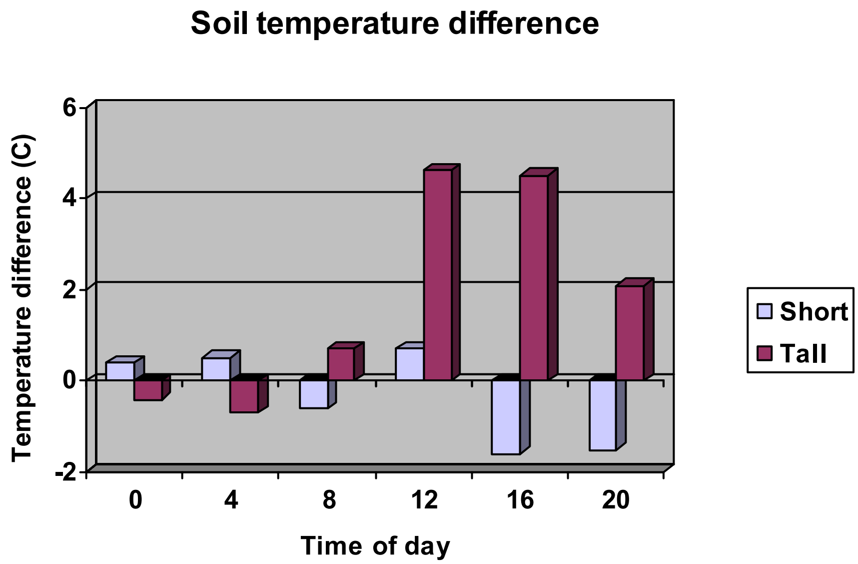


Figure 2. Mean daily surface soil temperature of short and tall stubble treatments at emergence. Values are expressed as the temperatures of short and tall stubble treatments, relative to cultivated stubble.

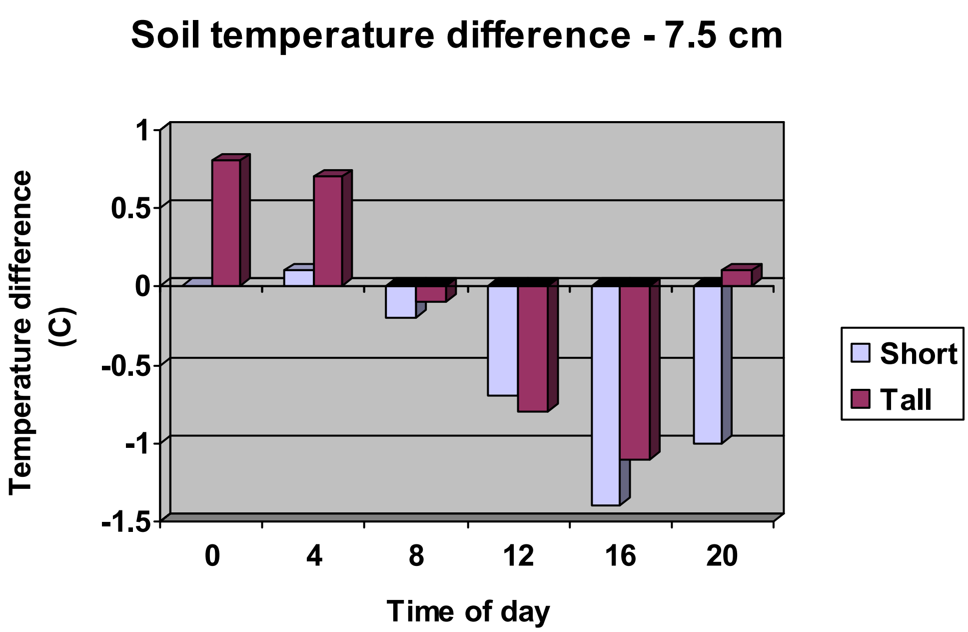


Figure 3. Mean daily soil temperature at 7.5 cm of short and tall stubble treatments at emergence. Values are expressed as the temperatures of short and tall stubble treatments, relative to cultivated stubble.

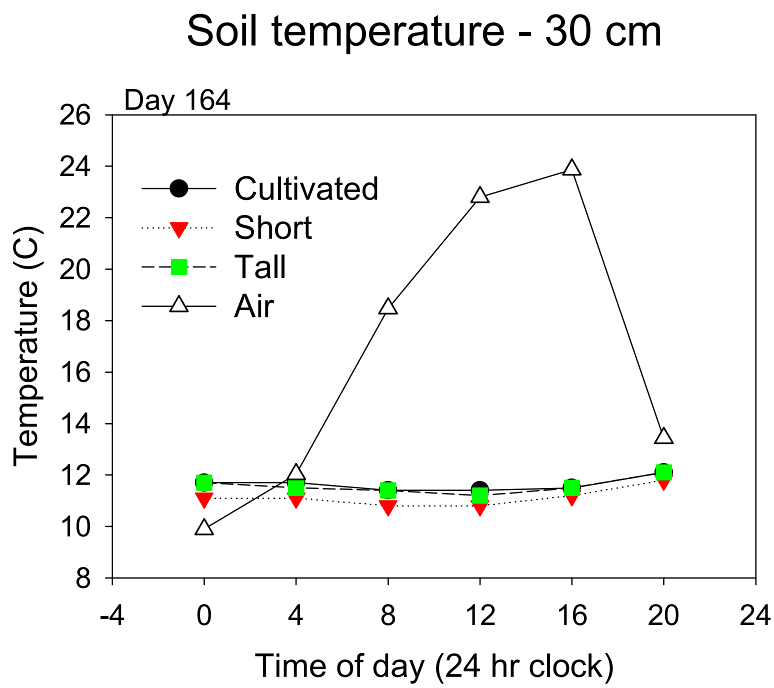


Figure 4. Mean daily soil temperature at 30 cm at emergence in response to stubble treatment.

Air temperature

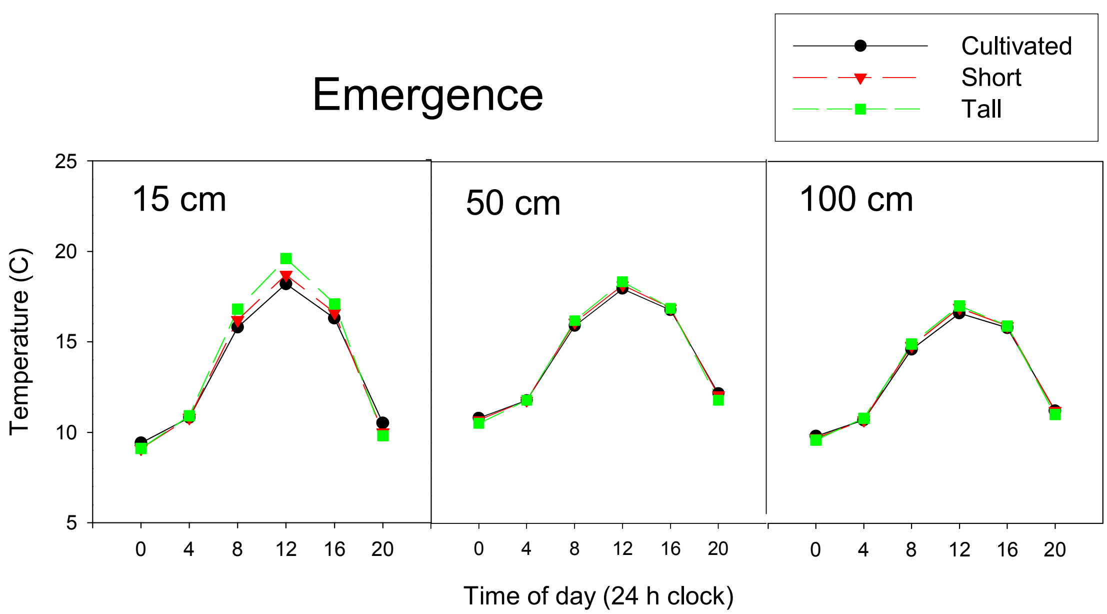


Figure 5. Mean air temperature at emergence at 15, 50 and 100 cm above the soil surface as affected by stubble treatment.

Stubble treatment increased day-time air temperature during the early stages of crop canopy formation (Figs 5 & 6). The effects of stubble on air temperature were most pronounced closer to the soil surface and decreased with elevation above the surface. In general stubble decreased air temperature relative to the cultivated treatment during the night time and increased air temperature relative to the cultivated treatment during the day (Fig. 6). Tall stubble had a greater influence on air temperature than shorter stubble. While this stubble effect on air temperature was most strongly expressed during early crop development it was still apparent six weeks after emergence (Fig. 7).

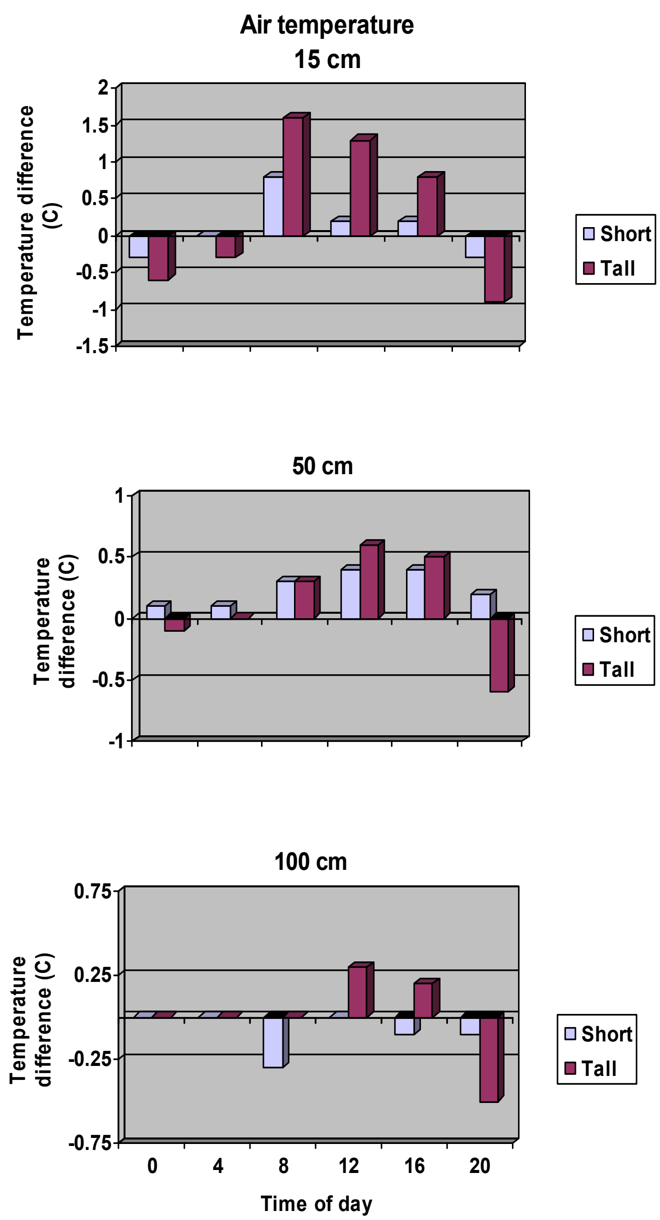


Fig. 6. Effect of short and tall stubble on air temperature, relative to cultivated stubble, at elevations of 15, 50 and 100 cm.

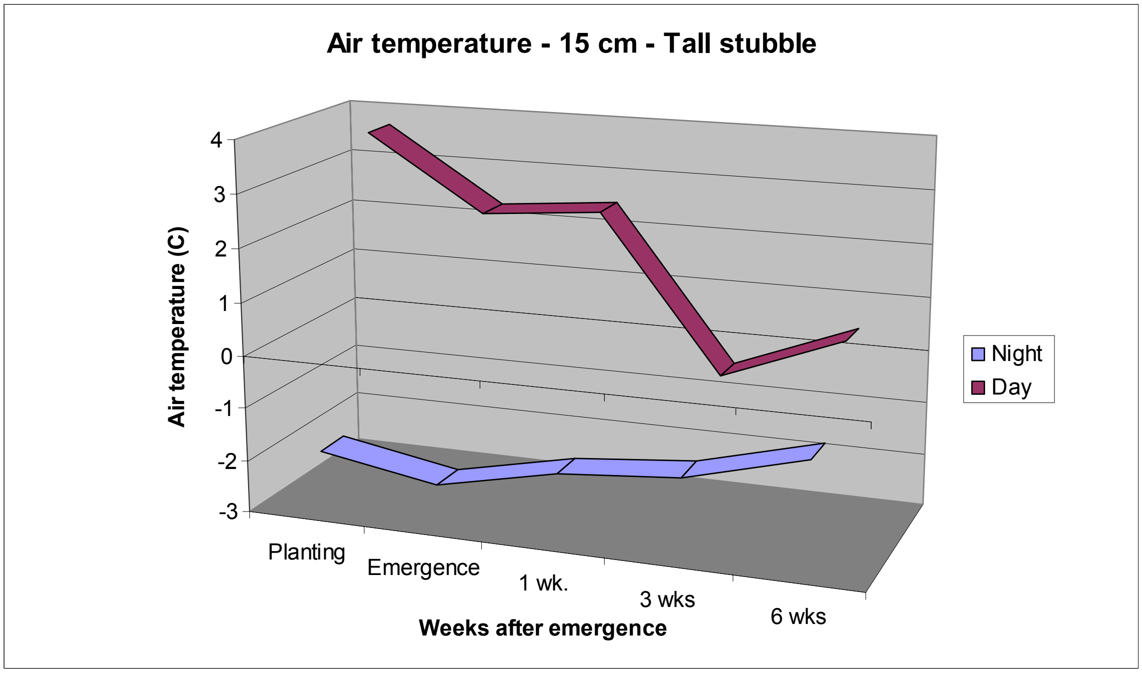


Fig. 7. Mean day- and night-time temperatures under tall stubble, relative to cultivated treatment at planting and up to 6 wks after emergence.

Soil moisture: Emergence and post emergence

There was a clearly defined pattern among stubble treatments in surface soil moisture measured using TDR. Short and tall stubble treatments had generally higher soil moisture contents than cultivated treatments well past the phase of early crop establishment (Fig. 8).

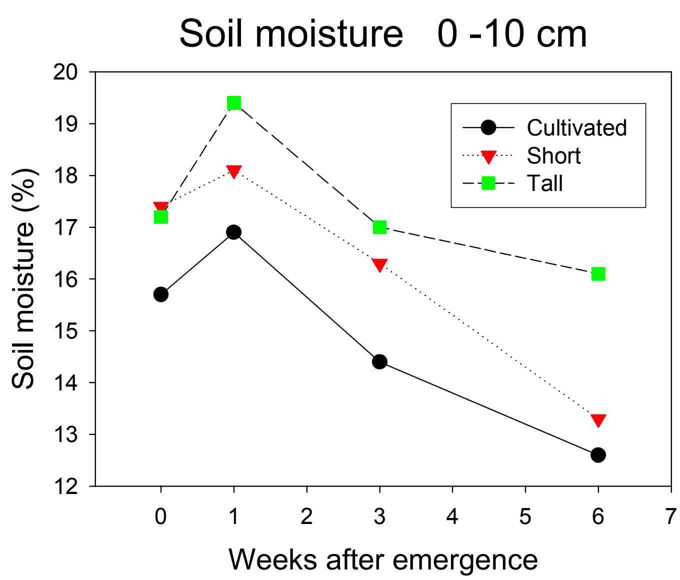


Figure 8. Soil moisture at 0-10 cm during crop establishment as affected by stubble height.

Wind speed
Stubble significantly reduced the rate of air movement 25 cm above the soil surface during early crop establishment (Fig 9). The effect of stubble treatment was negligible once crop height exceeded maximum stubble height.

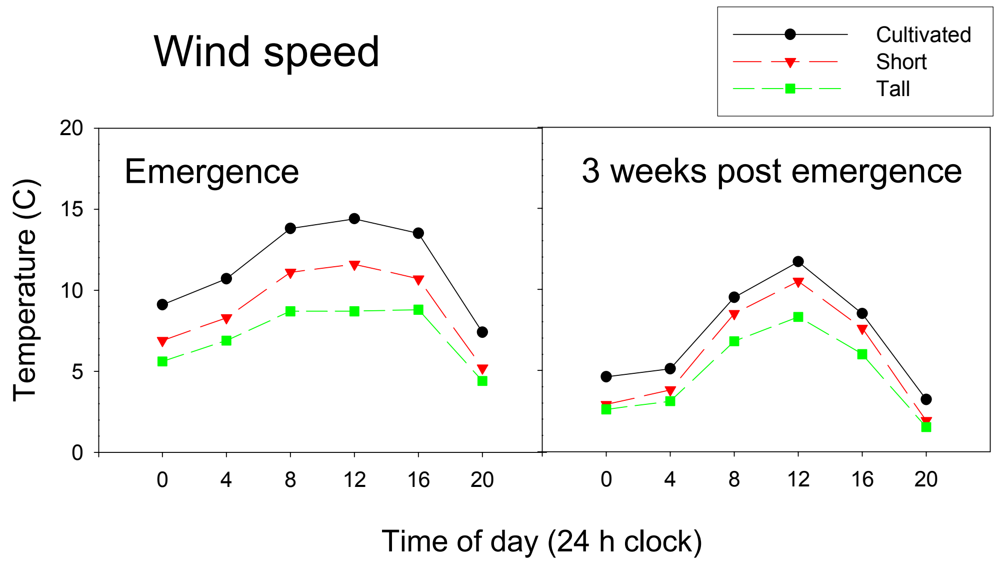


Figure 9. Mean daily wind speed at 25 cm above the soil surface at crop emergence and at three weeks after emergence, as affected by stubble treatment.

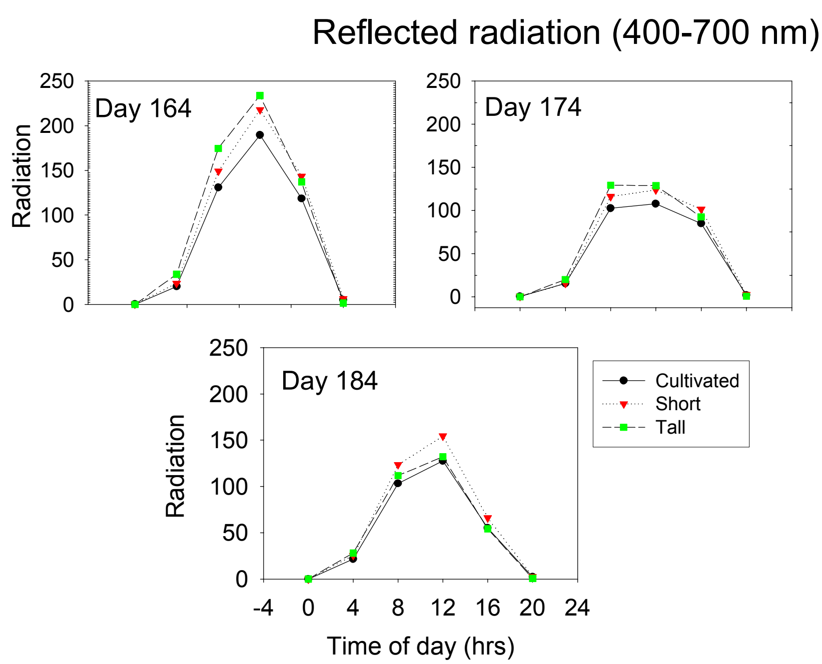


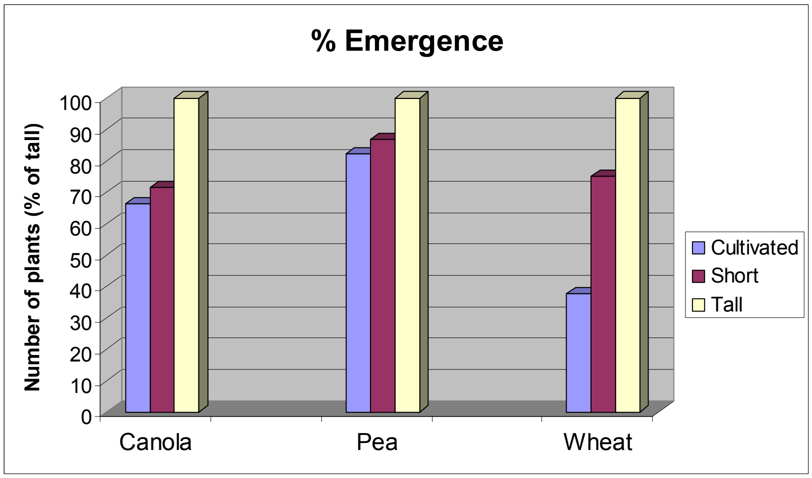
Figure 10. Reflected radiation measured at 200 cm elevation, at three growth stages, as affected by stubble treatment.

Reflected radiation
The amount of photosynthetically active radiation reflected from the crop canopy was higher in short and tall stubble compared to cultivated stubble during crop establishment (Fig. 10). However as early as 20 days after crop emergence (day 184) there were no differences between tall and cultivated treatments.

CROP PERFORMANCE

Seedling emergence
Seedling emergence was influenced by stubble height in all three years (Fig. 11 Both short and tall stubble increased plant number per square meter during early crop emergence. Canola and wheat were very responsive, particularly to tall stubble treatment, while pea was generally less responsive to both short and tall stubble.

Figure11. Effect of stubble height treatment on % seed emergence of canola, pea and wheat.



Mid-season plant biomass
Stubble height had a significant influence on plant biomass (Fig. 12). In general, there was a consistent trend toward increased biomass under tall stubble at each measurement date for all three crops.

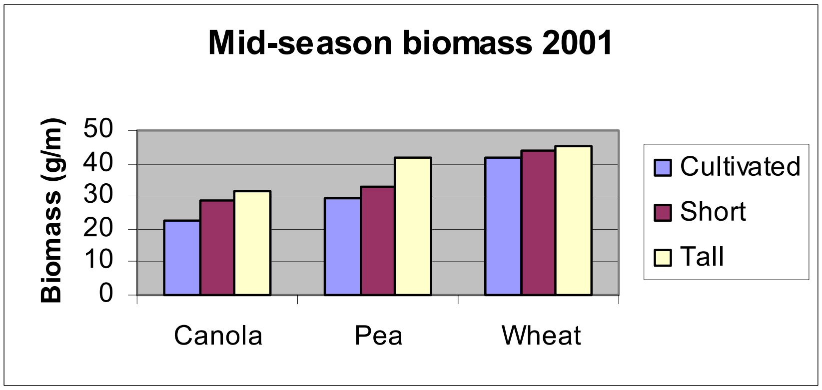


Figure 12. Effect of stubble height treatment on mid-season plant biomass (oven-dried weight) of canola, pea and wheat.

Crop yield
Yield at harvest was generally not significantly influenced by stubble height (Figure 13.). The exception to this was pea in 2002, where yields under tall stubble were significantly higher than under the cultivated treatment.

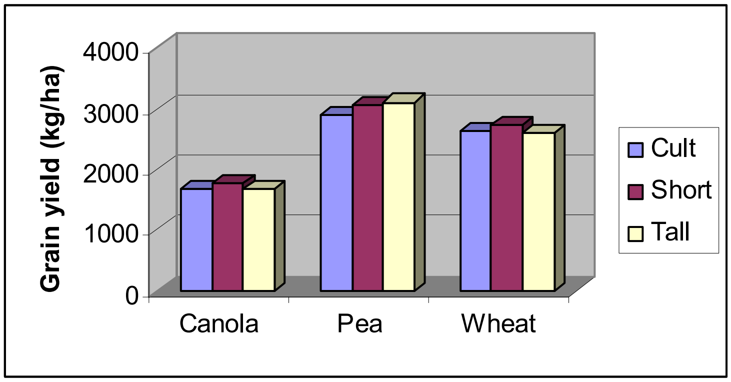


Figure 13. Effect of stubble height treatment on 2002 grain yield of canola, pea and wheat.

Discussion
Cereal stubble was found to delay day-time soil warming and night-time cooling, increase day-time canopy air temperature and decrease night-time air temperature, increase surface and sub-surface soil moisture, reduce wind speed near the soil surface, and increase crop canopy reflectance. These micro-climatic effects increased seedling emergence, vegetative biomass, but had minimal impact on final crop yield.

The changes observed in crop micro-climate may impact crop growth and development at several levels which could, in turn, influence crop productivity. Microbially-mediated processes like nutrient mineralization are sensitive to soil temperature and will occur at a slower rate at cooler temperatures. Rhizobial colonization and N-fixation are also sensitive to temperature. Cooler soils will reduce root growth rate, decreasing the rate of soil exploration by the root system, limiting crop access to both nutrients and water. Tall stubble decreased mean soil temperature in this study, and therefore probably influenced crop access to nutrients. On the other hand, tall stubble was found to increase day-time soil surface and air temperature. Elevated canopy temperatures will accelerate all processes associated with plant growth, as demonstrated in this study by higher plant emergence rates, and greater mid-season vegetative biomass. This early growth advantage increases yield potential through increased plants per unit area, increased seeds per plant, and increased seed weight.

Differences in surface soil moisture amongst stubble treatments are likely due to slower evaporation from the surface under short and tall stubble due to a thicker boundary layer reducing wind speed at the soil surface, as well as to cooler soils. Higher seed bed moisture is a critical factor in dry years, reducing the risk of seed mortality caused by rapid soil drying.

The early effects of tall stubble on stand establishment have an immediate and direct feedback effect on subsequent crop micro-climate. Increased plant per unit area increases the density of the boundary layer separating the soil surface from the atmosphere above the canopy. This was evident in the prolonged effect of stubble on air temperature, well past the time at which crop height surpassed the height of the tallest stubble.

Early improved crop performance under tall stubble did not consistently translate into higher yields. In all three years, tall stubble grain yield fell far short of the potential indicated by mid-season biomass yields. The reason for this is uncertain. One possible explanation is the lower than average precipitation that occurred during grain formation and filling in all three years of this study. Higher plant numbers draw more water from the soil, increasing the vulnerability of the crop to moisture stress if precipitation is irregular. This can have a significant negative impact on yield potential during influorescence. Another possibility is that the higher biomass associated with taller stubble increased nutrient demand, resulting in a nutrient deficiency.

Cutforth and McConkey (1996) reported the potential benefits of maintaining tall stubble in a semi-arid environment. The current study suggests that tall stubble confers a potential yield benefit under the sub-humid climate of Manitoba. Importantly, these results suggest that the practice of seeding into tall stubble is not economically disadvantageous. The savings associated with the reduced energy expenditure as a result of cutting the crop higher up the stem could reflect savings to the producer without a yield penalty.

Acknowledgements
We extend our thanks to R. Fortier, B. Sheardown, S. VanLankvelt, and G. Maline for their contributions to the successful completion of this study. Funding support from the Westen Grains Research Foundation for the stubble height component of this study is gratefully acknowledged.

References

Campbell, C.A., McConkey, B.G., Zentner, R.P., Selles, F. and Dyck, F.B. 1992. Benefits of wheat stubble strips for conserving snow in southwestern Saskatchewan. J. Soil and Water Cons. 47: 112-115.

Cutforth, H.W. and McConkey, B.G. 1997. Stubble height effects on microclimate, yield and water use efficiency of spring wheat grown in a semiarid climate on the Canadian Prairies. Can. J. Plant Sci. 77: 359-366.

Moulin, A.P., S.S. Malhi and D. Leach. 1998. Management of barley crop residue produced by combines equipped with stripper headers. P380-385 in Proceedings Saskatchewan Soils and Crops Workshop