

## Stubble Effects on Crop Micro-Climate and Yield

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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 to 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.

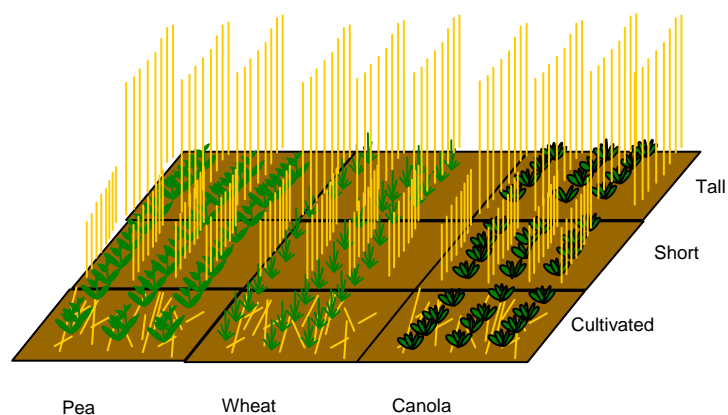
Past research has shown that tall stubble (35 cm or taller) increases crop yield and water use efficiency in semi-arid climate (Campbell et al. 1992; Cutforth and McConkey 1997). Based on their results, the authors recommended that producers in the semiarid prairies seed spring wheat directly into stubble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

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 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 partially randomized complete block, replicated four times. Figure 1 shows a schematic depiction of the stubble treatment by crop species layout. 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.



**Figure 1.** Schematic of one complete block of stubble x crop species.

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.

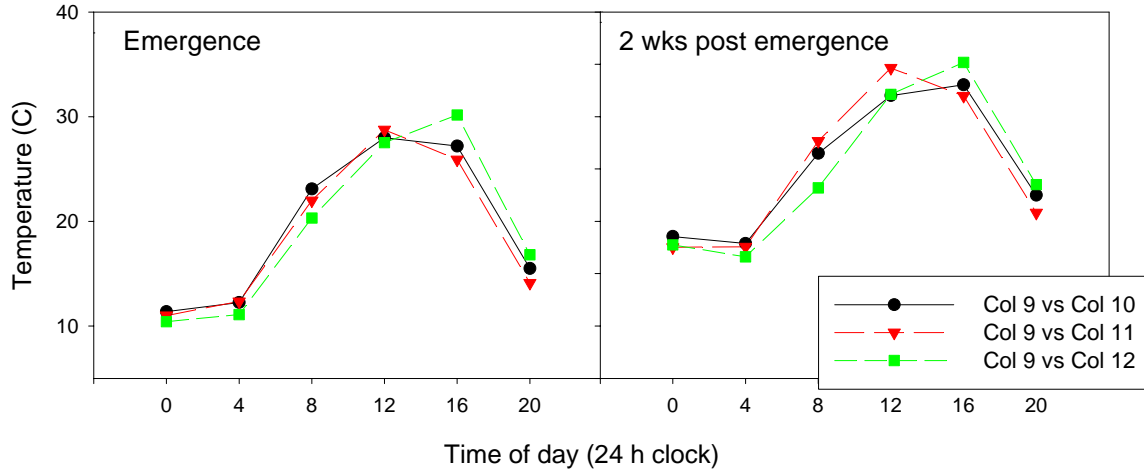
## Results

### Micro-climate

#### *Soil temperature*

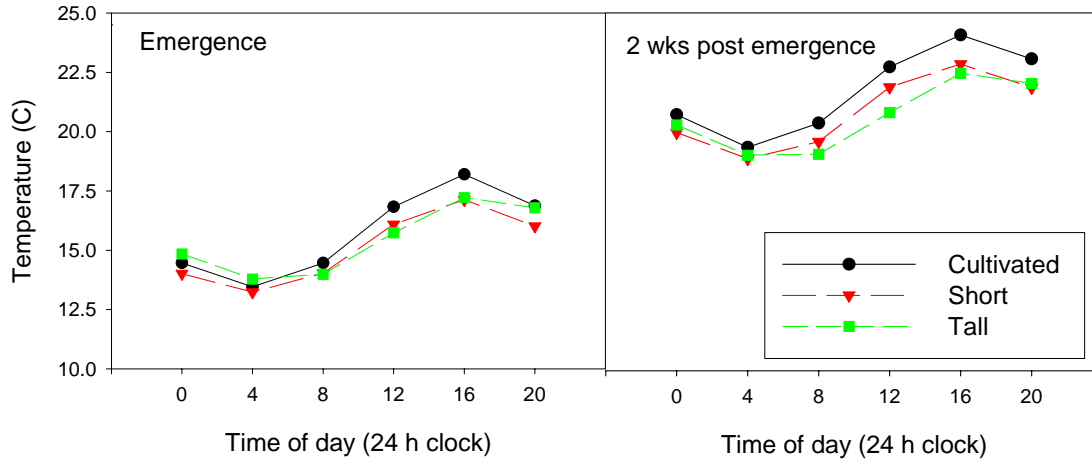
In general, during early stand establishment, stubble delayed night time cooling and day time warming at the soil surface and at 7.5 cm (Figures 2-4). During the period of emergence and two weeks after, both short and tall stubble caused surface and sub-surface soils to be cooler than cultivated soil. Three and six weeks after emergence this day-night differential effect of stubble was most evident below the soil surface.

### Surface soil temperature

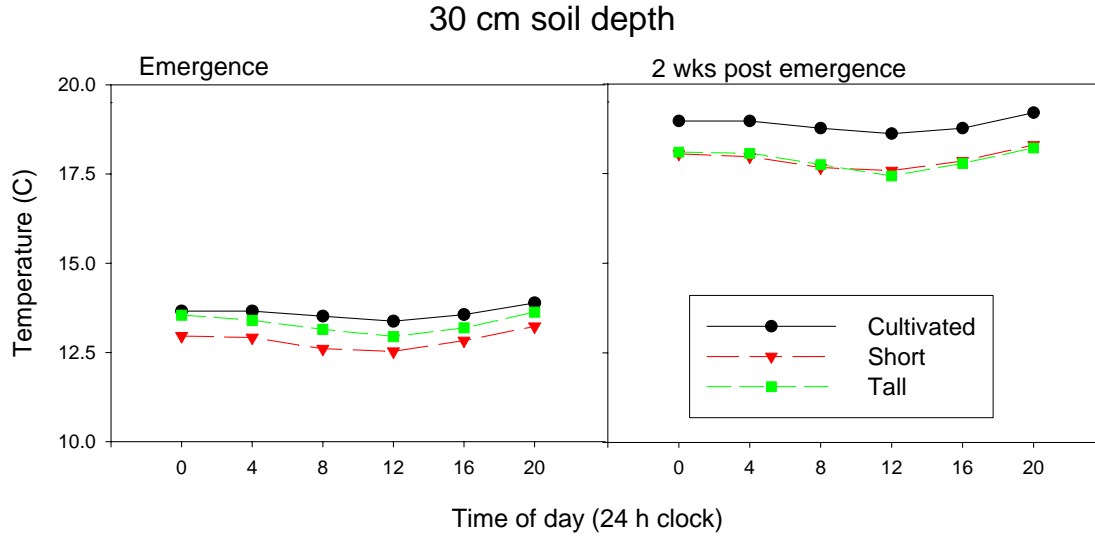


**Figure 2.** Mean daily surface soil temperature at emergence and two weeks after emergence in response to stubble treatment.

### 7.5 cm soil depth

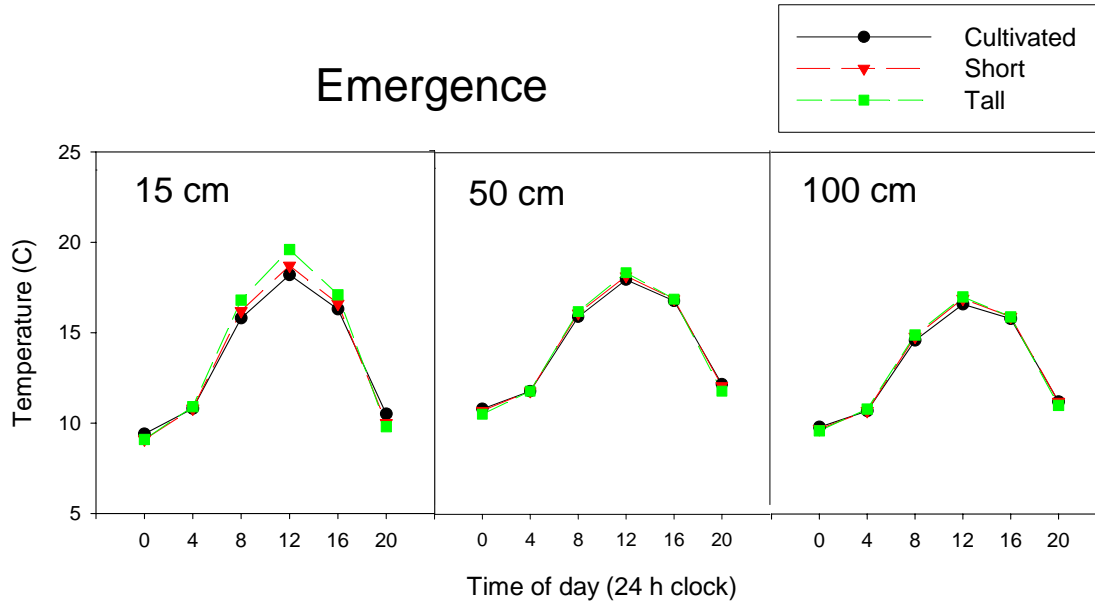


**Figure 3.** Mean daily soil temperature at 7.5 cm soil depth at emergence and 2 weeks after emergence in response to stubble treatment.



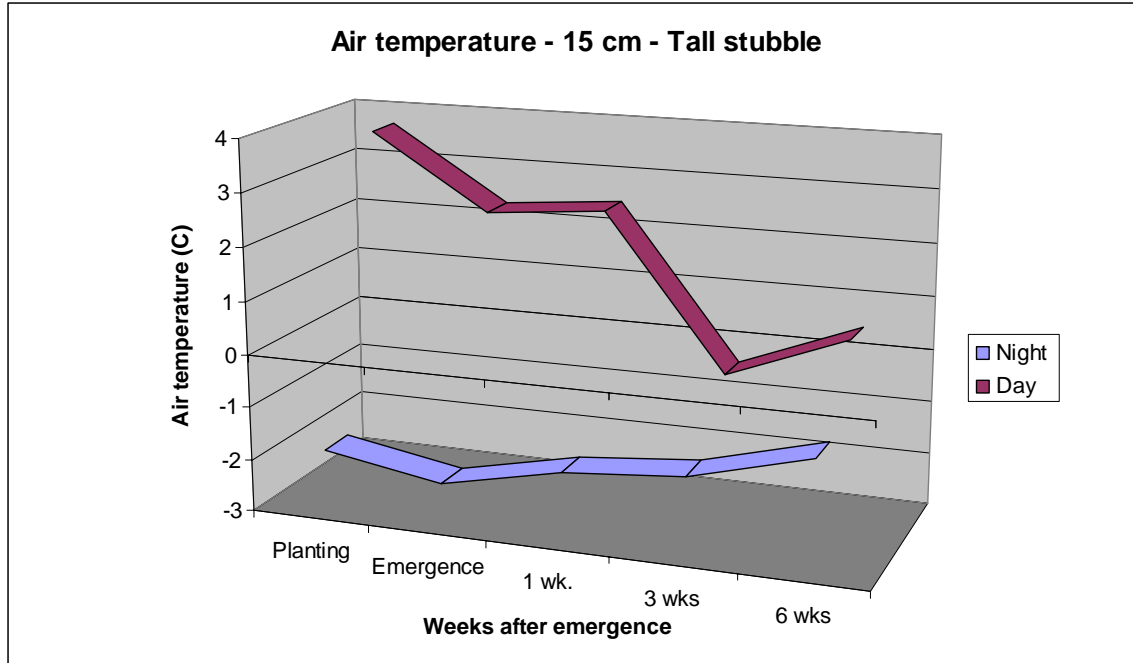
**Figure 4.** Mean daily soil temperature at 30 cm soil depth at emergence and 2 wks after emergence in response to stubble treatment

*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 (Fig 5). 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).



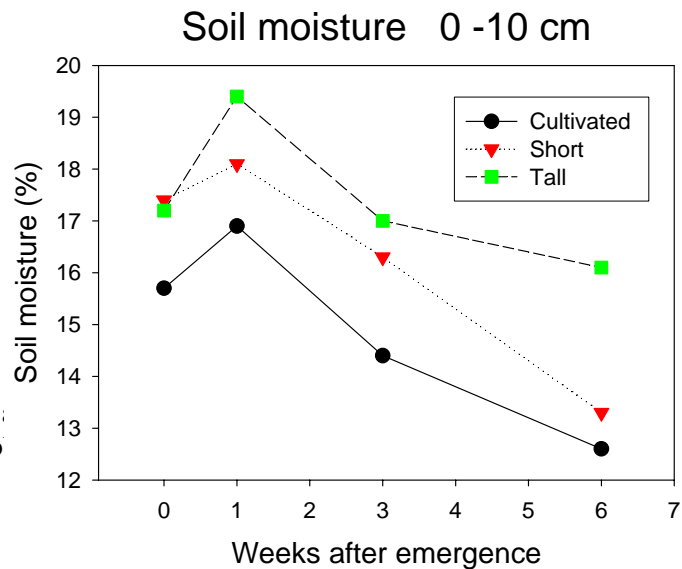
**Figure 6.** Mean day- and night-time temperatures under tall stubble, relative to cultivated treatment at planting and up to 6 wks after emergence.

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.

*Soil moisture: Emergence and post emergence*

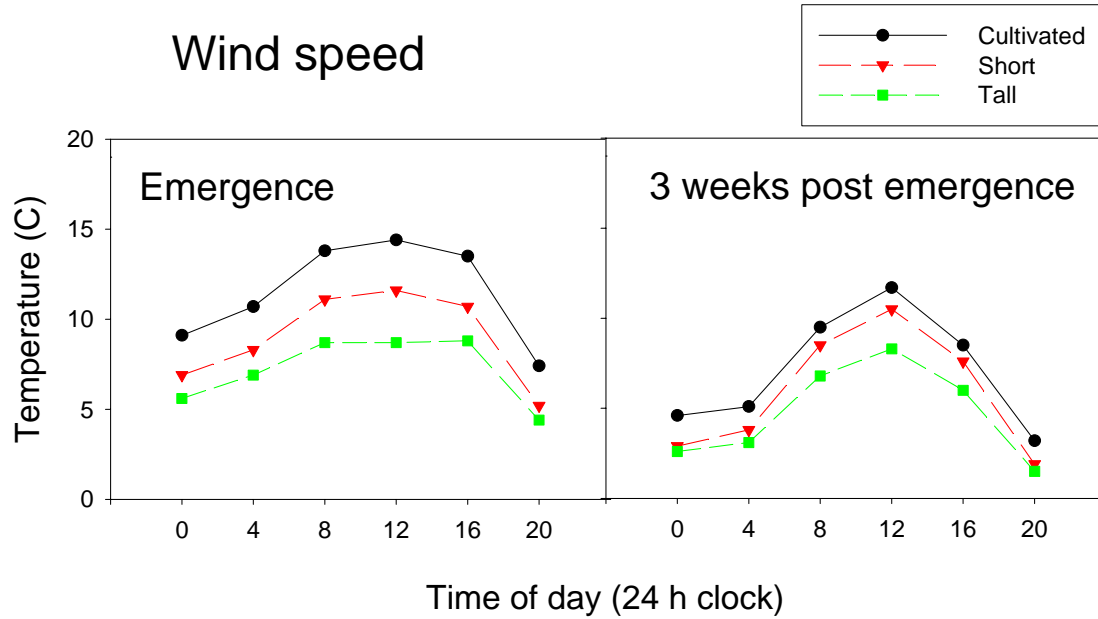
There was a clearly defined pattern among stubble treatments in surface soil moisture measured using TDR. Short and tall stubble treatments had generally higher soil moisture contents than cultivated treatments well past the phase of early crop establishment.

**Figure 7.** Soil moisture at 0-10 cm during crop establishment as affected by stubble height.



*Wind speed*

Stubble significantly reduced the rate of establishment (Fig 8). The effect of stubble maximum stubble height.



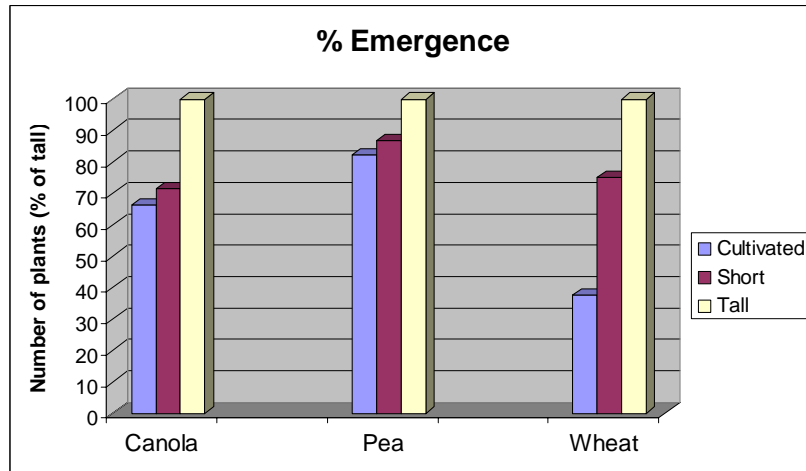
**Figure 8.** Mean daily wind speed at 25 cm above the soil surface at crop emergence and at three weeks after emergence, as affected by stubble treatment.

**Crop Performance**

*Seedling emergence*

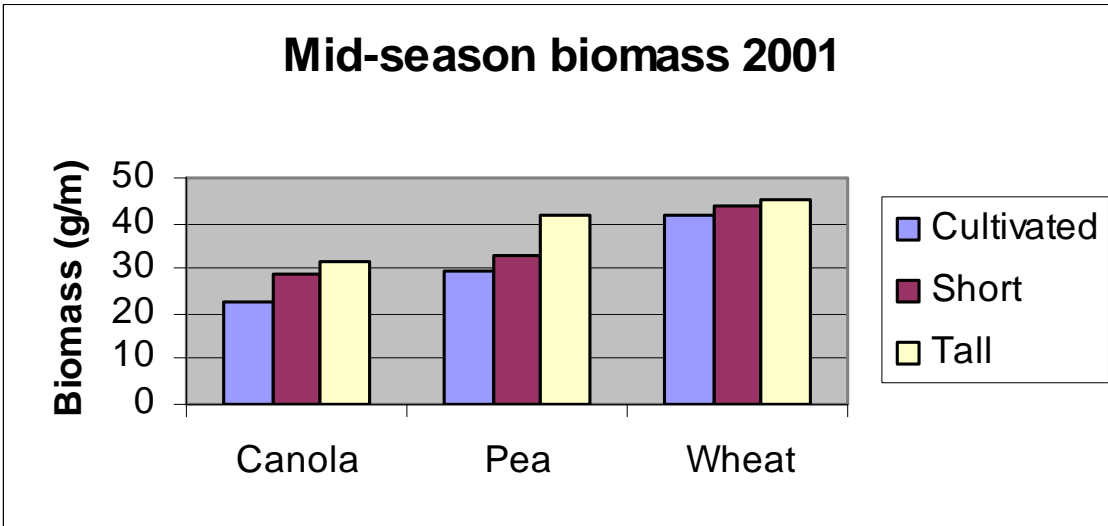
Seedling emergence was influenced by stubble height in all three years (Fig. 9). Both short and tall stubble increased plant number per square meter during early crop emergence. Canola and wheat were very responsive, particularly to tall stubble treatment, while pea was generally less responsive to both short and tall stubble.

**Figure 9.** Effect of stubble height treatment on % seed emergence of canola, pea and wheat.



*Mid-season plant biomass*

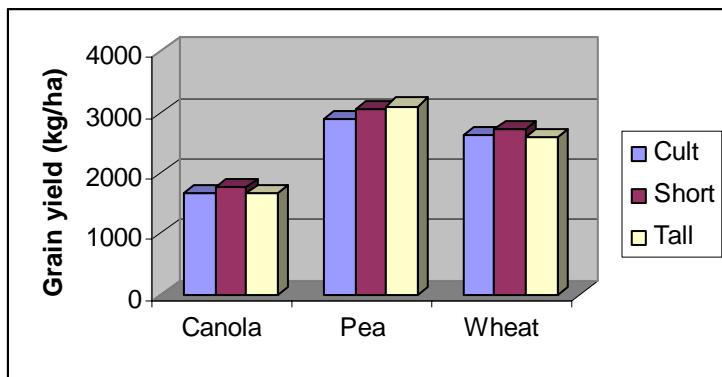
Stubble height had a significant influence on plant biomass (Fig. 10). In general, there was a consistent trend toward increased biomass under tall stubble at each measurement date for all three crops.



**Figure 10.** 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 11.). The exception to this was pea in 2002, where yields under tall stubble were significantly higher than under the cultivated treatment.



**Figure 11.** 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, increased day-time canopy air temperature and decrease night-time air temperature, increase surface and sub-surface soil moisture, and reduce wind speed near the soil surface. 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. This could limit 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 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 inflorescence. 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**

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