Direct Seeding: Water use, Yield, Residue Management

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Introduction
In dry climates where water availability is one of the major limiting factors to agricultural production, management practices that maximize economic returns per unit of water used are key to financial viability. Direct seeding into standing stubble is one management technique to increase water supply and/or use water more efficiently. During the snow-free fall and spring, surface residues conserve water by reducing evaporation of rain and soil water from the soil surface thus increasing water supply for the subsequent crop. Overwinter, the standing stubble traps snow, the amount trapped depends upon the height of stubble. Experience has shown that the benefits of snow trapping are variable depending on the amount of snow received and weather during snow melt. Regardless of whether the weather situation allowed standing stubble to significantly increase soil moisture, there are important in-crop effects of the standing stubble that positively affect the growing crop. The standing stubble alters the microclimate surrounding the growing seedlings (the alteration depends on stubble height) resulting in more efficient use of water, and alters the pattern of water use throughout the growing season.
During the following discussion, we will concentrate on the in-crop effect of direct seeding into standing stubble in semiarid or dry climates. The tabled results were analyzed across studies 4 years in duration.

Microclimate Alteration
When direct seeded into standing stubble, the microclimate within which seedlings are growing depends upon the height of the stubble. The table below illustrates the dependence of microclimate within 15 cm (6 inch) of the soil surface on stubble height. The plots overwintered as tall stubble to equalize snow trap and spring soil water reserves as much as possible. The stubble treatments were deployed shortly before seeding in spring. During the seedling stage, wind speed 15 cm above the soil surface depended upon the height of the stubble, with winds in the tall stubble less than a third of the wind speed measured above the cultivated plots. Average daily air temperatures at 6 inches above the soil surface were independent of stubble height, although there was a tendency for temperatures to be slightly higher in the tall stubble. Average daily soil temperatures at seeding depth (2 inch) were higher for the cultivated stubble compared to tall stubble. Crop phenology is affected by an average of the soil and air temperature immediately surrounding the seedling. Because average (of seeding depth and 6 inch air) temperatures were similar, stubble height had little effect on crop phenology. Solar energy penetrating the stubble to within a couple of inches of the soil surface was reduced by the 12 inch stubble compared to the 6 inch and cultivated stubble. As stubble height increased, the reduction of wind speed and solar energy near the soil surface reduced the potential evaporation of water from minilysimeters located close to the soil surface. Compared to the cultivated stubble, tall stubble reduced potential evaporation by more the 25%. This implies that standing stubble conserves water by reducing evaporative water losses, either from the soil surface or from plant surfaces, and that the magnitude of the reduction is dependent upon stubble height.

Stubble Height*	Wind ($m\ s^{-1}$)	Air T (C)	Soil T (5 cm - C)	Rad. ($MJ\ d^{-1}$)	Evap. ($g\ H_2O\ h^{-1}$)
Tall (12 in.)	0.5c	14.1	14.4b	17.9b	2.34c
Short (6 in.)	1.3b	13.8	14.6ab	20.1a	2.85b
Cultivated	1.7a	12.4	15.2a	20.2a	3.17a

*stubble height imposed just before seeding

Crop Water Use

Water use measured from changes in soil moisture is a combination of water used productively by the crop and water evaporated from the soil surface. In a water limited environment, any water not evaporated from the soil will be used by the crop. Hence, in our stubble-height trials where we left the stubble tall right until seeding, as shown in table below, there was no difference in water use between stubble heights. Crop water use will be shifted slightly under tall stubble with less water use early in the season (due to lower evaporation of water from crop and soil) than under cultivated stubble and more water use later in the growing season when the larger crop plant consumes all the conserved soil moisture.

Stubble Height	Spring Wheat	Pulse	Canola
Tall (12 in.)	309	240	273
Short (6 in.)	314	242	271
Cultivated	309	246	275

Grain Yield

Although water use was independent of stubble height, grain yield was definitely affected by stubble height. Whether spring wheat, pulse or canola, grain yield increased as stubble height increased. Compared to cultivated stubble, tall stubble increased yields, on average, by about 12%.

Stubble Height	Spring Wheat	Pulse	Canola
Tall (12 in.)	2560a	2008a	1410a
Short (6 in.)	2418b	1858ab	1334b
Cultivated	2255c	1782b	1239c

Water Use Efficiency

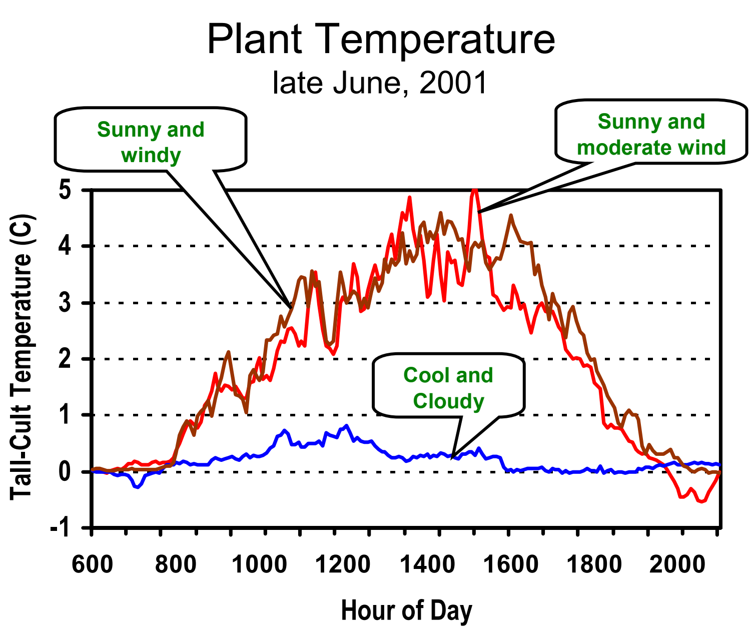
The increased grain yield as stubble height increased did not come from increases in water supply so arose because the crops used water more efficiently. As shown in the table below, the water use efficiency (grain yield divided by water use (kg/ha/mm)) increased as stubble height increased.

Stubble Height	Spring Wheat	Pulse	Canola

Tall (12 in.)	8.4a	8.7a	4.8a
Short (6 in.)	7.9ab	8.1ab	4.7ab
Cultivated	7.5b	7.5b	4.5b

There are several reasons why water use efficiency increases as stubble height increases. Although in a semiarid environment total water use during the growing season is not affected by stubble height, the pattern of water use during the growing season is affected by stubble height. To simplify a complicated process, crop water use, or evapotranspiration, is composed of two major components, evaporation losses from plant and soil surfaces, and transpiration losses through the plants. Crop residues on the soil surface reduce evaporation losses of water from the soil surface, and the magnitude of the reduction increases as stubble height increases. Reducing the evaporation losses from the soil surface increases the amount of water available for transpiration by the crop.

Microclimatic alterations near the soil surface, especially wind speed, affect heat dissipation by the seedlings. From the figure below, canola seedlings growing in tall stubble can be as much as 5 C higher in temperature on sunny days than seedlings growing in cultivated stubble. There is little difference in seedling temperature on cloudy days when the plants are not being much warmed by solar radiation. However, on sunny days the plant temperature for the plants grown in tall stubble is up to 5°C higher than those grown on cultivated stubble. These temperature differences on sunny days are relatively independent of wind speed 2 m (6.5 feet) above the soil surface. The reason for the temperature difference reflects the effect of tall stubble on reducing wind speeds within the canopy. The reduced wind speed decreases heat loss from air movement over the leaves and decreases evaporation of water from the plant (transpiration). On the prairies, where plant growth is more limited by low temperatures than hurt by excessive temperatures, the increased above-ground plant temperature increases canopy growth rates. The higher above-ground plant temperatures also compensate for any developmental delay due to lower below-



ground plant temperatures under standing stubble.

Extra-Tall Stubble
Producers now have the capability to seed directly into stubble 20+ inches in height. Does this extra-tall (X-tall) stubble adversely affect crops, or will the advantages of taller stubble over cultivated stubble continue to increase with X-tall stubble? When averaged across the past 3 years (of a planned 4 year study) and across spring wheat, canola and chickpea, water use was independent of stubble height, but yields were dependent upon stubble height with crop yields highest from X-tall stubble and lowest from the cultivated stubble treatment. Water use efficiency (WUE), although not significant, showed a very strong tendency to increase with increase in stubble height. We expect that after another year of results, water use will continue to be independent of stubble height, but that both grain yield and water use efficiency will increase as stubble height increases.

Stubble Height	Water use mm	Yield ($kg\ ha^{-1}$)	WUE ($kg\ ha^{-1}\ mm^{-1}$)
X-tall (18+ in.)	215a	1551a	8.5a
Tall (12 in.)	215a	1486ab	8.0a
Short (6 in.)	215a	1423ab	7.5a
Cultivated	215a	1329b	7.1a

Canola was more consistently responsive to stubble height than spring wheat or chickpea.

Stubble Height	Spring Wheat	Canola	Chickpea
X-tall (18+ in.)	2070a	1164a	1403a
Tall (12 in.)	2030a	1119ab	1309a
Short (6 in.)	1925a	1006bc	1339a
Cultivated	1907a	872c	1209a

Residue Management
* Good chaff spreaders and straw chopper/spreaders that spread residue well are essential equipment to have before attempting to seed into tall stubble. Maintaining the spreaders in optimum condition will reduce horse-power requirements, save fuel, optimize spread of residue, and reduce residue-related seeding problems the following spring.

* In some residue situations, heavy harrowing can help spread straw after harvest.

* Attaining good soil-seed contact is the seeding goal so residue management must also consider the type of seeder. Disc-openers are most appropriate for seeding into tall stubble whereas hoe-type openers (knife, hoe, spoon, or sweep) mounted on a shank are best suited to shorter stubble. When planning the purchase of a seeder, the producer should consider if he/she may direct seed into tall or very tall stubble in the future.

* Producers contemplating the purchase of a stripper-header should spend a good deal of time considering how they intend to manage the very tall stubble between harvest and seeding the following spring. They need to consider if their seeding equipment can handle the extra-tall stubble without modifications to the seeder itself, or modifications to the stubble height after harvest.

* A producer who direct seeds into shorter stubble but is now considering direct seeding into taller stubble must determine if he/she has the seeding equipment that can adequately accommodate the change.

* As a general rule-of-thumb, hoe-type drills should not be used to seed into stubble taller than the row width. Under conditions where both the straw and soil surface are dry and the straw has been spread evenly across the field, hoe drills sometimes work adequately in stubble up to one and a half times taller than row width. But when the soil surface is wet and/or the straw is damp, hoe-type drills and taller stubble do not mix.

* Disc drills work well in stubble much taller than row width. In fact, the lower the amount of straw lying on the ground, the better.

* Attachments such as the 'Smart Hitch' that allow the hoe-type opener to track between two adjacent rows of standing stubble can improve the work-ability of hoe-type openers in stubble taller than row width. In Australia, producers have been able to seed between the rows using precision GPS-based guidance systems that depend on locally derived and transmitted GPS-correction signals.

* Producers contemplating a change in seeding and, therefore, residue management, such as purchasing a stripper-header, direct seeding into taller stubble, etc., should seek advice from other producers, researchers, extension agents, equipment manufactures, etc. Direct seeding equipment is expensive and adequate preparation before purchasing to reduce the chance of unpleasant surprises is one of the best management tools a producer has.

Summary
In a semiarid environment, increasing stubble heights to at least 18+ inches has a beneficial effect on yield and water use efficiency of cereal, canola and pulse crops. Good residue management and proper opener selection are key to the success of direct seeding into standing stubble, especially when seeding into taller stubble.