TECHNICAL NOTES

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INTRODUCTION

The following information regarding the influence of crop residue on frost formation was presented by J.L. Pikul, Jr. at the annual field day of the Columbia Plateau Conservation Research Center, USDA-ARS, Pendleton, Oregon. **This technical note was revised from Agronomy Technical Note – 22 July 1982.

Bare soil conditions from excessive tillage are expected to correlate with the data regarding stubble removal by burning.

FORMATION OF SOIL FROST AS INFLUENCED BY CROP RESIDUE MANAGEMENT

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Frozen soil has been implicates as a major factor contributing to high soil erosion losses in the Pacific Northwest. Soil losses can be especially high during heavy rainfall or rapid snow melt when subsurface frozen soil layers are present. Serious erosion has occurs even on soils that were not frozen more than 12 centimeters deep. Consequently, differences in tillage and residue management could have significant effects on fronts formation and hence erosion control. A frozen solid layer greatly reduces internal water movement much like a severely compacted soil does. This poor internal-drainage condition impairs water movement into the soil profile thereby increasing runoff and soil erosion.

Repeated soil freeing at night and thawing during the day, as occurs in late winter, is also suspected as a wasteful natural mechanism because it encourages evaporation rather than storing water in the soil. As the soil surface freezes, water migrates from deeper soil layers toward the freezing front, and then freezes. Because the frozen layers hold a large amount of water, a thaw during the day often produces saturated conditions in soil layers near the surface. Evaporative water loss under these conditions is especially high because evaporation then proceeds at a rate similar to that for a free water surface.

Preliminary indication are that crop residue cover and tillage both have a significant impact on soil freezing. However, because of the difficulty of research involvement, very little information is available on the mechanisms for frost formation and how management affects the process involved. The objects are to: 1) test and improve the prediction of soil frost based on commonly available meteorological information, and 2) determine which tillage, compaction and residue management techniques reduce the severity of soil frost in the winter and enhance water conservation during the summer.

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METHODS

Field plots were established on a Walla Walla silt loam at the Columbia Plateau Conservation Research Center near Pendleton during 1979 and 1981. One 40-meter site was selected on a uniform 30-meter high wheat stubble field. In September one-half the area was burned, leaving a bare surface. On the remaining half, inter-row chaff was redistributed uniformly over the soil surface. Surface residues were 9,000 and 13,500 kg/ha (4 and 6 tons/acre) for 1979 and 1981, respectively. To restrict our comparison to the presence and absence of surface residue we did no tillage.

Each plot was instrumented to measure soil temperatures at numerous depths down to 60 centimeters, air temperatures and windspeeds at various heights up to 120 centimeters above the surface. Both incoming and outgoing components of shortwave and longwave radiation were measured. Soil surface heat flux was measured with heat flux plates. Frost depth was measured daily during freezing weather by hand sampling.

RESULTS

Frost penetration and duration were different under burned stubble and standing wheat stubble during 1980 (Figure 1). Soil freezing began on January 17. our first frost depth observations were made during a partial thaw on January 24. During the ensuing period from January 25 to February 1, the average air temperature dropped to -10.5$^?$C and five centimeters of snow covered the plots. On February 2, the snow melted and partial soil thawing during the day followed by nighttime refreezing occurred through February 6. Maximum frost penetration during this freeing period was 28-20 centimeters in the burned and stubble plots, respectively. Average air temperature for the February 2 to 13 thaw period was 1.2$^?$C. On the stubble plot, the ice lens had decomposed into a soft, poorly defined layer on February 10, but a hard, well defined ice lens remained in the burned plot until February 14.

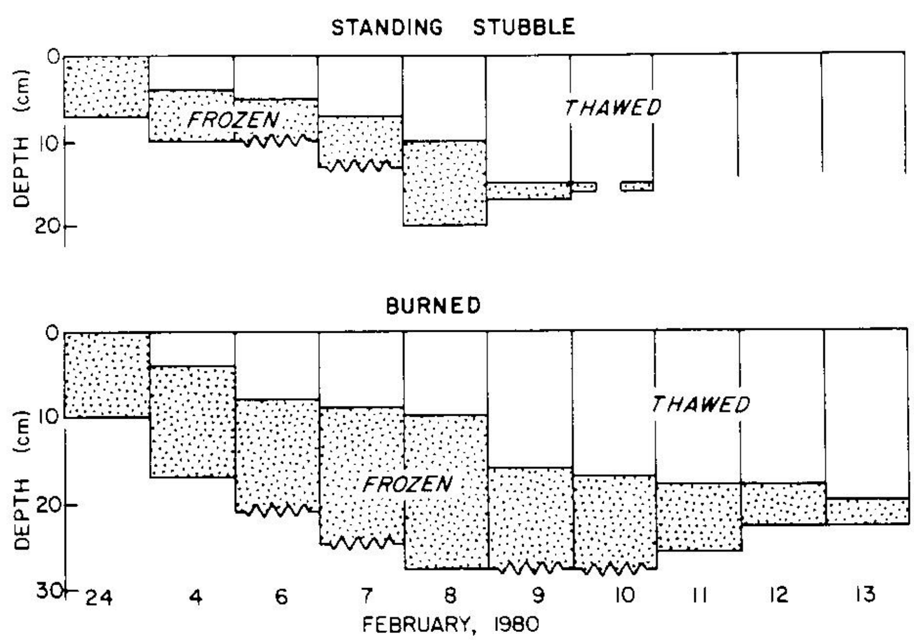

Figure 1. Depth of soil frost under standing stubble and burned stubble in late January and early February 1980

In 1982, frost penetration was again sensitive to the surface treatment, but the duration was nearly the same in both surface treatments (Figure 2). Soil freezing began February 3, but in contrast to 1980, there was no snow cover during the freezing period from February 3 to 9. Average air temperature for the freezing period was -6.3?C. Maximum frost penetration was 21 and 15 centimeters for the burned and stubble plots, respectively. Both plots were completely thawed on February 15, however the stubble plot thawed slightly earlier as evidenced by a decomposed, poorly defined ice lens on February 14.

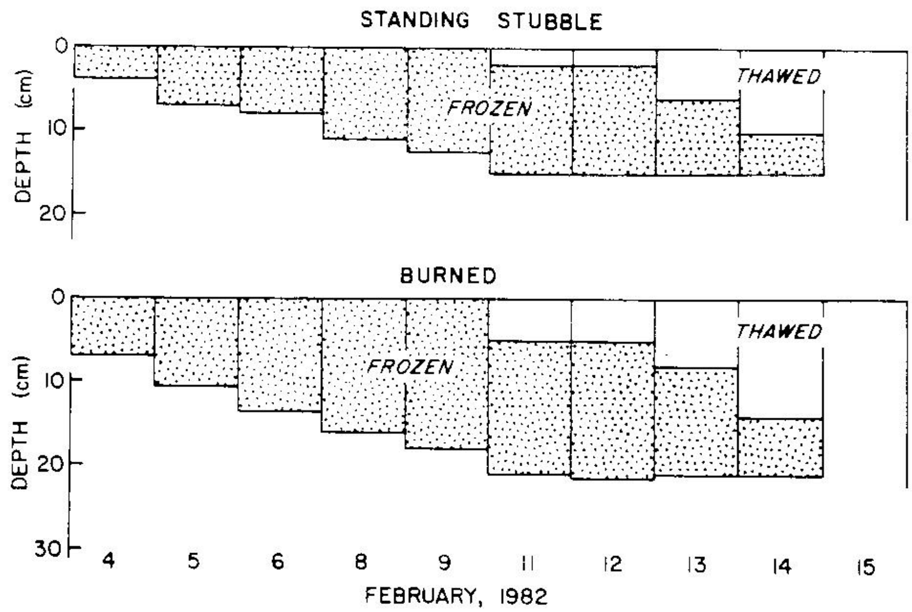

Figure 2. Depth of soil frost under standing stubble and burned stubble in early February 1982.

Soil heat flux was measured to understand causes for the different freezing depths in the stubble-covered compared to burned plots in 1980 (Figure 3). With the exception of the partial soil thaw on January 24, large heat losses (negative values) are associated with soil freezing. From January 25 to February 1, air temperatures remained below freezing and significant differences of soil heat loss occurred between the two plots. Standing stubble acted as a thermal insulating layer over the soil surface, and, therefore, reduced soil heat loss by 40 percent and reduced the depth of frost penetration by 30 percent as compared to the bare plot. The thawing period of February 2 to 13 was characterized by low air temperatures and cloudy conditions. Positive heat flux into the bare surfaces plot was 20 percent greater than into the standing stubble. Although heat input was greater on the bare surfaced plot, it was not enough to offset frost depth differences between the burned and stubble plots. Consequently soil thawing occurred five days later on the bare surfaced plot.

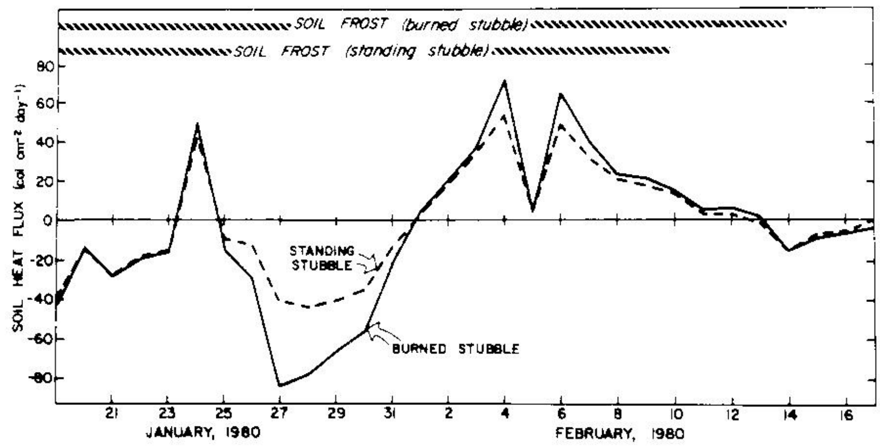

Figure 3. Soil surface heat flux for standing stubble and burned stubble in late January and early February 1980. Presence of soil frost is indicated by a solid bar.

In 1982, soil heat flux measurements during freezing and thawing were again sensitive to surface crop residue (Figure 4). At the onset of soil freezing, on February 3, both plots typically exhibited high heat loss. Significant heat loss differenced between the two plots developed during February 4 to 9 when air temperatures remained below freezing. Standing penetration by 30 percent as compared to the bare surface plot. The rapid thawing period of 1982 was characterized by clear days and warm air temperatures (7.5?C). Heat flux into the bare surfaced plot was 40 percent greater than into the standing stubble. Both plots thawed the same day, because high heat input into the bare surface had offset the differences in frost depth.

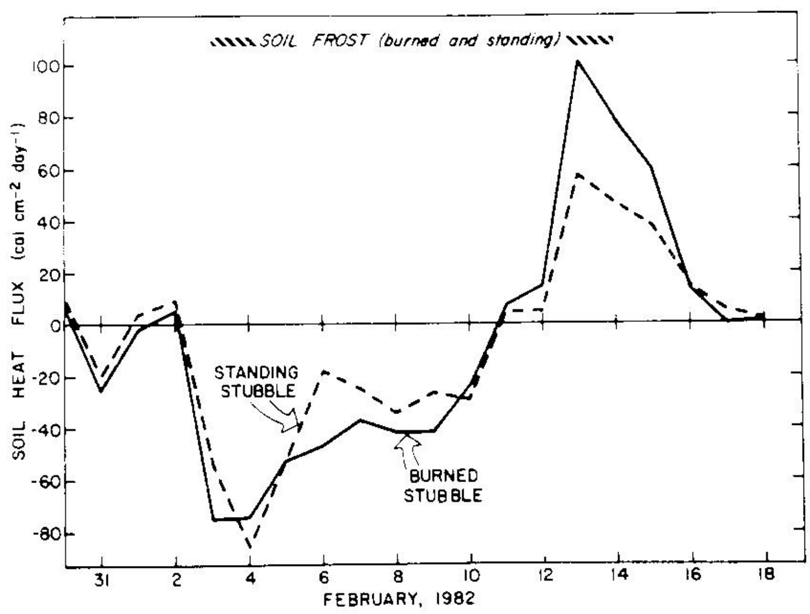

Figure 4 Soil surface heat flux for standing stubble and burned stubble in early February 1982. Presence of soil frost is indicated by a solid bar.

CONCLUSIONS

For the two winters of 1980 and 1982, standing stubble consistently reduced the depth of frost penetration by 30 percent as compared to a bare surfaced plot. However, the persistence of soil frost is linked to both the soil surface and the prevailing weather conditions during the thaw. Surface residue did not influence the duration of soil frost during the clear sky, rapid thawing conditions of 1982. But during the thaw of 1980, when cloudy and low daytime temperatures were accompanied by freezing to near-freezing nights, straw on the surface favored soil thawing. Weather conditions during the 1980 thaw would be typical for the moisture laden, frontal type storm systems of this area. Appreciable rainfall during the advance of the storm systems would pose a serious erosion threat because a frozen layer impedes water infiltration from surface to subsurface layers. Soil frost is a liability for soil erosion. If frost is in the ground and rainfall exceeds the infiltration capacity, then conditions are prime for accelerated soil erosion.