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EFFECT OF WINTER WHEAT SEEDING DATE ON SOIL EROSION IN THE WEST-CENTRAL GREAT PLAINS

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ABSTRACT—In the west-central Great Plains, the risk of soil erosion due to wind is high, particularly during winter. One way to reduce soil erosion is to plant winter wheat (*Triticum aestivum L.*) early in the season, so that the crop establishes four tillers prior to the onset of winter dormancy. Currently, however, wheat is seeded late in the planting season to reduce disease and insect infestation. In this study, we evaluated potential soil erosion in relation to seeding date. Using historical climate data, we determined the probability that winter wheat plants will establish four tillers prior to dormancy at 55 sites throughout the west-central Great Plains using current seeding dates. For many locations, the currently recommended planting date results in a low probability of achieving the growth required to reduce soil erosion. Planting one to three weeks earlier would reduce the potential of soil erosion during winter months. The use of earlier seeding dates, however, will depend upon the development of wheat cultivars that have improved disease and insect resistance.

Introduction

The risk of soil erosion due to wind is high in the west-central Great Plains, particularly during the winter months, when there is little plant cover

(Johnson et al. 1983). To hold the soil and reduce soil erosion, winter wheat (*Triticum aestivum* L.) can be planted early in the growing season, so that the crop establishes at least four tillers prior to the onset of dormancy. However, for many locations in the west-central Great Plains, winter wheat is planted late in the season to reduce potential infestation by pests, such as pathogens, insects, and weeds that reduce yield. For instance, timing of winter wheat seeding affects the severity of diseases, such as wheat streak mosaic virus (Hunger et al. 1992), root and crown rot (*Bipolaris sorokiniana* Shoem. and *Fusarium* spp.) (Fenster et al. 1972), and Cephalosporium stripe (*Cephalosporium gramineum*) (Pool and Sharp 1969). A later planting date also reduces the damage caused both by insects, such as Hessian fly (*Mayetiola destructor*) (Cook and Veseth 1991) and Russian wheat aphid (*Diuraphis noxia*) (Legg et al. 1991), and by weeds, such as downy brome (*Bromus tectorum* L.) (Massee 1976).

Winter wheat develops in an ordered sequence that can be predicted from daily accumulations of temperature within crop-specific threshold values. These accumulated temperatures are known as thermal heat units or growing degree days (GDD) (Klepper et al. 1982). With an understanding of this developmental process, wheat growth and development can be modeled from seeding to maturity (McMaster et al. 1991; McMaster et al. 1992). The combination of historical climate data with information on growth and development have been used to suggest the best seeding date in order to produce a winter wheat crop.

The two objectives of this study were to: 1) assess the probability of a winter wheat crop establishing four tillers before dormancy using currently recommended seeding dates, and 2) identify planting dates that would allow sufficient fall growth to avoid undesirable soil erosion in the west-central Great Plains.

Methods

In our model, winter wheat growth was assumed to stop when soil temperature at 10 cm fell to 0°C and remained at or below this level for the remainder of the winter. The 10 cm depth was used since soil temperatures at that depth are more stable than those at the plant's crown depth (2.5 cm). A soil temperature climatology was developed using data from the High Plains Climate Center's Automated Weather Data Network (Hubbard et al. 1983). Data from 25 automated weather stations across the study region (9-15 yr) were used to determine the average date of soil freeze.

The climate data used to accomplish the two objectives of this study were derived from the National Weather Service cooperative observer network and first order stations. We used 47 years of data (1949-1995), the maximum length of digitized record for many locations in the west-central Great Plains.

Previous research suggested that wheat seeded in optimal, suboptimal, and dry seedbeds requires 80, 90, and 100 growing degree days (GDD) to germinate, respectively (McMaster et al. 1992; Wilhelm et al. 1993). And, seedling emergence occurs at a rate of 0.50 mm, 0.40 mm, and 0.33 mm per GDD, respectively. Full emergence of the first tiller requires 330 GDD. And full emergence of each tiller thereafter requires 110 GDD (Table 1). For this study, we assumed initial conditions that are typical in the west-central Great Plains, i.e., suboptimal soil moisture conditions and a seeding depth of 3.5 cm. Thus, under these conditions, 840 GDD are required to establish the four tillers required to provide the desired ground cover for reducing soil erosion prior to the onset of dormancy [*germination* (90 GDD) + *seedling emergence* ((3.5 cm / (0.40 mm/GDD)) + *first tiller emergence* (330 GDD) + *emergence of next three tillers* (3 tillers x 110 GDD/tiller)]. Growing degree days (GDD) were calculated using an upper threshold temperature of 30°C and a lower threshold temperature and base temperature of 0°C.

Climate data for 55 locations in the west-central Great Plains were analyzed using a software package that determines probabilities of specific climatic events (ClimProb: Meyer et al. 1996). After determining the mean date of fall growth cessation (average date of soil freeze), ClimProb was used to determine: 1) the probability of a winter wheat crop accumulating the 840 GDD, and so establishing four tillers prior to the onset of dormancy using the currently recommended winter wheat seeding date; and, 2) the required seeding date for the crop to establish four tillers prior to dormancy in nine of ten years. The 90% probability level was selected to reflect the high cost of soil erosion and the conservative nature of the Great Plains producer.

Nebraska and Colorado recommend specific seeding dates. The other three west-central Great Plains states recommend 10-day seeding windows: 15-25 September in South Dakota, 1-10 September in Wyoming, and 10-20 September in Zone 1 in northwestern Kansas. A 40-day seeding window (1 September-20 October) is recommended in north central to southwest Kansas (Zone 2). Our analyses were performed using the first day in the seeding window, i.e., 15 September for South Dakota, 1 September for Wyoming, and 10 September for Kansas.

TABLE 1
Germination rates, seedling emergence rates, and tiller emergence rates of winter wheat based on accumulated growing degree days (30°C upper threshold temperature, 0°C lower threshold temperature and base temperature)

	Growing Degree Days (°C)		
	Optimum Seedbed	Suboptimum Seedbed	Dry Seedbed
Germination Rates	80	90	100
Seedling Emergence Rates	0.50 mm/GDD	0.40 mm/GDD	0.33 mm/GDD
Full Emergence of First Tiller	330	330	330
Full Emergence of Each Subsequent Tiller	110	110	110

Adapted from McMaster et al. (1992) and Wilhelm et al. (1993).

The probability of a winter wheat crop establishing four tillers prior to the onset of dormancy using the currently recommended winter wheat seeding date was determined by back-calculating 840 GDD from the average date of soil freeze for each of the 47 years in the data set. Similarly, the seeding date required for the crop to establish four tillers prior to the onset of dormancy in nine out of ten years was determined by back-calculating 840 GDD from the average date of soil freeze, then determining the date on which 840 GDD had accumulated in 90% of the 47 years in the data set.

Results

Average date of soil freeze ranged from the end of November, in southwestern South Dakota and northwestern Nebraska, to mid-December, in southwestern Kansas (Fig. 1). Standard deviation of soil freeze dates across most of the west-central Great Plains ranged from 6 to 8 days, except

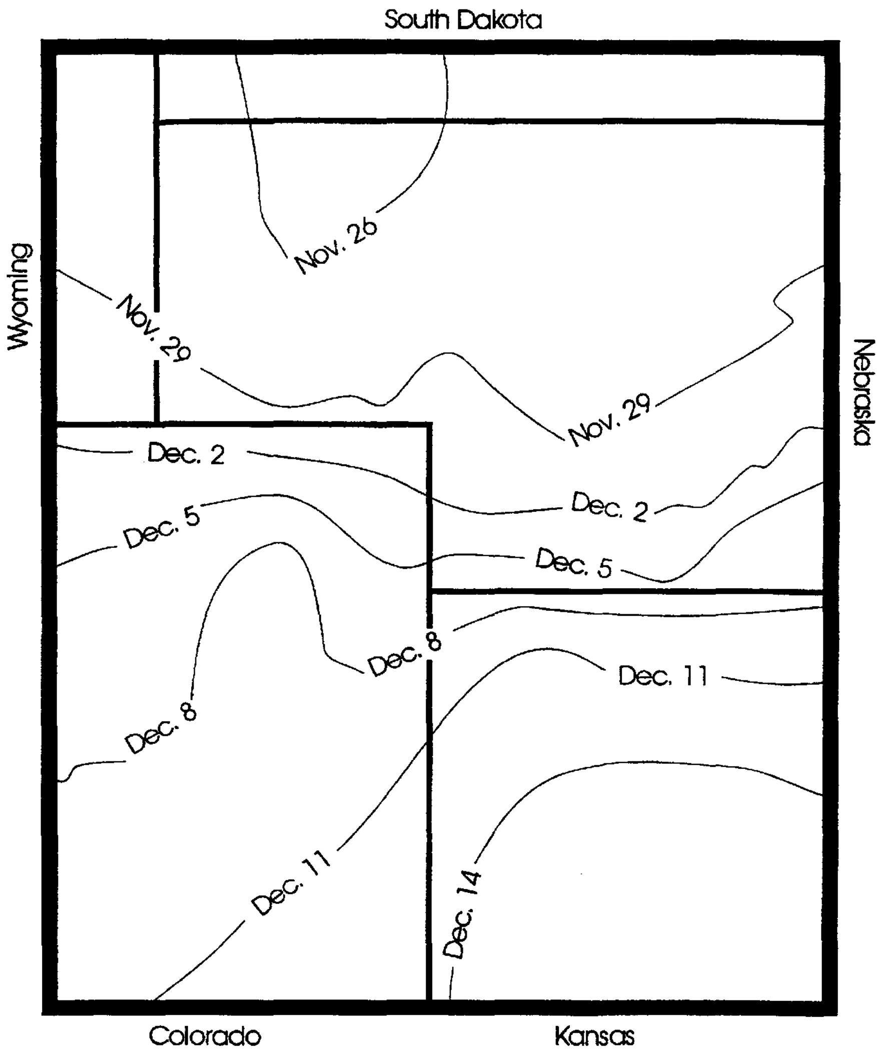

Figure 1. Average date for soil temperature at 10 cm to decline to 0°C.

in eastern Colorado, which ranged from 8 to 9 days. Standard deviations may have been greater in Colorado because those automated weather stations had the shortest length of record (9 years).

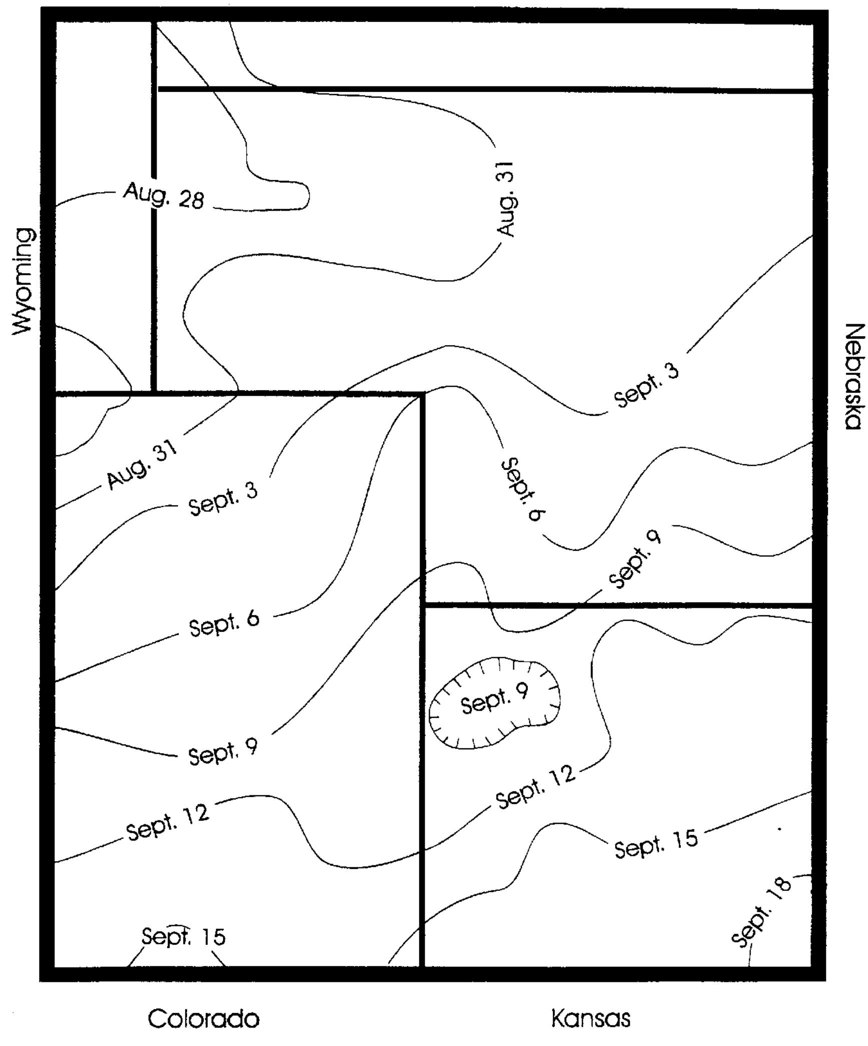

Figure 2. Seeding date required to accumulate sufficient thermal heat units (840 GDD) by the average date of soil freeze (90% confidence).

Required seeding dates for west-central Great Plains winter wheat to establish four tillers prior to dormancy in nine out of ten years vary (Fig. 2). These dates range from late August in Wyoming, southwestern South Dakota, the Nebraska Panhandle, and north central Colorado to mid-September

in southwestern Kansas (Table 2). Reducing the confidence level from 90% to 80% delayed the required seeding date by just 1 to 2 days at all 55 study sites.

In South Dakota, the probability of accumulating enough thermal heat units (840 GDD) to grow four tillers prior to dormancy, using the recommended seeding date, is extremely low, 3-5%, at all three locations (Table 2). The seeding date required for the crop to establish four tillers prior to dormancy, with 90% certainty, was a full two weeks earlier than currently recommended (Table 2). The seeding date recommended for southwest South Dakota is intended to reduce the likelihood of early fall infection by barley yellow dwarf virus and wheat streak mosaic virus, both of which have insect vectors (C. E. Stymiest, personal communication, 1996).

In Wyoming, the probability of accumulating sufficient thermal heat units (840 GDD) by the average soil freeze date was relatively high, 47-85%, at the four sites (Table 2). For Torrington and Chugwater, which are located in river valleys where lower elevation accounts for slightly warmer temperatures, the required seeding dates for establishing four tillers prior to dormancy (90% confidence) were within 1 to 3 days of the recommended seeding dates. However, for Lusk and Cheyenne, which are located in the higher elevations of Wyoming, required seeding dates for comparable development were a full week earlier than current dates.

In Colorado, which has recommended, but unpublished winter wheat seeding dates (J. T. Shanahan, personal communication, 1995), the probability of accumulating adequate thermal heat units (840 GDD) to establish four tillers prior to dormancy using the recommended seeding dates, is very low, 2-28%, except in the two southernmost locations, Lamar and Rocky Ford (Table 2). The difference between the date recommended and the date required to establish four tillers before soil freeze was particularly great (two full weeks) in northeastern Colorado. For the remaining Colorado locations, the difference ranges from 8-10 days. As in South Dakota, the later seeding date in northern and eastern Colorado is recommended to reduce the potential of early fall infestation by wheat streak mosaic virus and barley yellow dwarf.

Similarly, in Nebraska, the probability of accumulating sufficient thermal heat units (840 GDD) prior to dormancy using the recommended seeding date was extremely low for nearly all study sites (Table 2). In the southwestern part of the state, these probabilities range from 0-3%. Growers in the southwest use 25 September as the "Hessian fly-free" date, the date recommended to avoid Hessian fly damage to wheat seedlings. Although

TABLE 2

Important dates for winter wheat, date of: soil freeze, date recommended for seeding, and date to accumulate 840 GDD (for 4 tillers) before freeze

	Soil Freeze Date	Seeding Date	Probability of Accumulating 840 GDD	Seeding Date Required to Accumulate 840 GDD
South Dakota				
Hot Springs	11/26	9/15	3%	8/31
Martin	11/26	9/15	5%	8/31
Oelrichs	11/26	9/15	4%	9/1
Wyoming				
Upland Sites				
Cheyenne	12/1	9/1	55%	8/25
Lusk	11/27	9/1	47%	8/25
River Valley Sites				
Chugwater	11/29	9/1	64%	8/29
Torrington	11/28	9/1	85%	8/31
Nebraska				
Panhandle Sites				
Harrison	11/27	9/2	28%	8/24
Kimball	11/30	9/3	68%	8/30
Mitchell	11/28	9/9	21%	8/30
Scottsbluff	11/28	9/10	15%	9/1
Sidney	11/30	9/7	38%	9/1
Sandhills Fringe Sites				
Alliance	11/26	9/10	5%	8/29
Arthur	11/28	9/15	3%	9/1
Bridgeport	11/27	9/13	9%	9/4
Gothenburg	11/30	9/15	17%	9/5
Kingsley Dam	11/29	9/15	17%	9/6
Madrid	11/30	9/15	19%	9/7
North Platte	11/29	9/15	3%	9/2
Oshkosh	11/29	9/16	3%	9/2
Southwest Sites				
Benkelman	12/6	9/25	3%	9/9
Cambridge	12/4	9/25	2%	9/10
Culbertson	12/4	9/25	0%	9/6
Hayes Center	12/2	9/25	0%	9/5
Holdrege	12/4	9/25	3%	9/7
Imperial	12/2	9/25	0%	9/8

TABLE 2 (continued)

	Soil Freeze Date	Seeding Date	Probability of Accumulating 840 GDD	Seeding Date Required to Accumulate 840 GDD
Colorado				
Northeastern Sites				
Holyoke	12/2	9/17	4%	9/6
Julesburg	11/30	9/20	3%	9/6
Sterling	12/4	9/17	2%	9/3
Northern Sites				
Akron	12/8	9/12	28%	9/4
Burlington	12/9	9/20	11%	9/10
Byers	12/7	9/15	23%	9/6
Cheyenne Wells	12/10	9/20	23%	9/10
Fort Morgan	12/7	9/15	15%	9/5
Southern Sites				
Lamar	12/11	9/20	47%	9/13
Rocky Ford	12/11	9/20	51%	9/15
Kansas				
Zone 1 Sites				
Colby	12/12	9/10	77%	9/8
Goodland	12/10	9/10	77%	9/8
Hoxie	12/12	9/10	98%	9/14
Norton	12/8	9/10	98%	9/12
Oberlin	12/8	9/10	92%	9/12
Quinter	12/12	9/10	96%	9/11
St. Francis	12/8	9/10	96%	9/11
Tribune	12/12	9/10	98%	9/12
Zone 2 Sites				
Cimarron	12/14	9/10	100%	9/17
Dodge City	12/14	9/10	100%	9/17
Hays	12/13	9/10	98%	9/14
Healy	12/14	9/10	98%	9/14
Lakin	12/14	9/10	100%	9/16
Larned	12/14	9/10	100%	9/19
Ness City	12/14	9/10	98%	9/16
Phillipsburg	12/8	9/10	98%	9/14
Scott City	12/14	9/10	100%	9/16
Syracuse	12/13	9/10	100%	9/16
WaKeeney	12/12	9/10	98%	9/12

wheat growers in southwestern Nebraska need to heed the fly-free date, late planting can also retard fall growth. Differences between the date recommended and the date required for the crop to establish four tillers before dormancy (90% confidence) ranged from 15-20 days. For the rest of the Nebraska sites, the differences between the date recommended and the date required for establishment of four tillers ranged from 8-14 days. These recommended seeding dates are set to avoid early fall infestations of wheat streak mosaic, crown and root rot, and Russian wheat aphid, in addition to Hessian fly.

In Kansas, recommended seeding dates are defined as seeding windows for sites in two large zones (Shroyer 1986). Although the window length for the two zones differ—10 days in the northwestern and 40 days in the southwestern and north central—both windows begin on 10 September, the date we used in our analysis. The early seeding date recommended in Kansas virtually assures that the crop will accumulate the necessary thermal heat units (840 GDD) prior to the onset of dormancy (Table 2). However, if winter wheat producers in Kansas zone 2 do not seed their crop within the first week of the recommended seeding window, chances that the crop will establish four tillers prior to the onset of dormancy decrease rapidly.

Conclusions

Based on our analysis, the risk of soil erosion in the west-central Great Plains is high using recommended seeding dates. The risk of inadequate soil cover, potentially resulting in increased soil erosion, is assumed in order to reduce the probability of crop loss due to potentially devastating diseases in every state examined, except in Kansas which has an early recommended seeding date. The erosion risk is likely to persist until better disease and insect resistance can be developed in winter wheat to allow for earlier seeding, or there is a major shift in tillage systems from conventional tillage to no-till. Conventional tillage disturbs the soil surface, increasing the likelihood of soil erosion. No-till practices leave the soil undisturbed which helps hold the soil in place. However under no-till conditions, insect and disease pressure will likely be higher than under conventional tillage (Watkins et al. 1995). Development of winter wheat cultivars with improved disease and insect resistance provides the most direct strategy to reduce direct economic losses to pests, as well as to reduce indirect, long-term economic losses caused by soil erosion in the west-central Great Plains.

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