Precipitation effects on ridges created by grain drills

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ABSTRACT: The influence of precipitation on soil ridge height persistence was measured at 15 sites in five counties across Kansas. Multiple regression equations were developed to describe how ridges created by grain drills change in height over time. Cumulative precipitation was the major factor affecting ridge persistence. Secondary factors were soil texture (sand, silt, clay), soil organic matter, and exchangeable calcium. These results will be useful in modeling wind erosion across ridged surfaces and in determining the soil ridge roughness factor in the present wind erosion equation.

SURFACE ridges prevent or reduce wind erosion by influencing soil particle transport in the saltation and surface creep modes. Ridges properly oriented to wind direction trap saltation and surface creep aggregates and affect both mean and turbulent wind flow profiles over the ridges.

Ridge height influences trapping efficiency and sheltered trapping volume, which may determine if ridges fail during erosive storms on long fields (*4*). Wind tunnel work by Armbrust and associates (*1*) led to development of a relationship between ridge height and spacing and the soil ridge roughness factor, K, in the wind erosion equation (*5*). The K factor is a measure of the effect of ridges on erosion rates compared with a smooth (nonridged) surface.

Because rainfall dissipates soil ridges created by tillage operations, we sought to determine how long ridges created by grain drills persist for several soil textures and rainfall regimes.

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Study methods

In 1983-1984 we selected three sites of different soil textures in Riley County, Kansas. To establish different rainfall regimes, we selected two sites per county in 1984-1985 in Bourbon, Riley, Russell, Ford, and Stanton Counties, spanning Kansas from east to west. In 1985-1986 we selected two sites in Riley County. We installed height measuring devices across three or four drill ridges after seeding winter wheat with disk or hoe-type drills. Wheat was planted in the furrows. No additional surface cover was present. We used two or three replications on each soil.

We measured ridge-furrow heights to the nearest 0.5 mm following fall wheat seeding (usually in October) and four to eight more times until about the first week in May of the next year. We made the measurements in Riley County (1983-1986). Measurements in the other four counties were made by Soil Conservation Service personnel (1984-1985).

We installed rainfall gauges at each soil site in Riley County; rainfall data for the other counties came from the nearest gauging station.

From surface soil samples (0-8 cm), we determined particle size distribution (sand, silt, clay) using standard pipette methods (Table 1). Organic matter and exchangeable calcium were determined by the Kansas State University Soil Testing Laboratory.

Results and discussion

We correlated the main variables (Table 1) and their interactions with two dependent variables using stepwise multiple regression techniques. The first dependent variable was the ratio of ridge height at any given time after drilling to the original ridge height (Hi/Ho). The best one-, two-, and three-variable regression equations, using data from all sites, were as follows:

$$Hi/Ho = 0.9948 - 0.1087\,(Pc)^{0.5};\quad r^2 = .714 \qquad [1]$$

$$Hi/Ho = 1.0269 - 0.1106\,(Pc)^{0.5} - 0.0146\,S/Si;\quad R^2 = .749 \qquad [2]$$

$$Hi/Ho = 1.0754 - 0.1095\,(Pc)^{0.5} - 0.0197\,S/Si - 0.0067\,(OM)^2;\quad R^2 = .781 \qquad [3]$$

where Pc = cumulative precipitation (cm), S = sand content (%), Si = silt content (%), and OM = organic matter (%).

We separated the Riley County data from the other data and repeated the regression procedures because there were 3 years of data available, all collected by the same person, and precipitation was measured on-site. Corresponding single- and two-variable regression equations were as follows:

$$Hi/Ho = 1.0181 - 0.1464\,(Pc)^{0.4};\quad r^2 = .903 \qquad [4]$$

$$Hi/Ho = 1.0582 - 0.1417\,(Pc)^{0.4} - 3\times10^{-8}\,SSiCa;\quad R^2 = .932 \qquad [5]$$

where Ca is exchangeable calcium (ppm).

As expected, cumulative precipitation was the primary factor influencing changes in ridge height over time. However, secondary soil properties were highly significant in accounting for variation in ridge height, especially when all the sites were included in the analyses (Equations 2 and 3). These results agree with those of Dexter (*3*), who related changes in random roughness created by tillage in Australia to cumulative kinetic energy of rainfall. That parameter may describe rainfall effects on ridges better than cumulative precipitation, but rainfall intensity data were not available in our study. Also, it is not clear how kinetic energy can be used when part of the precipitation occurs as snow, as it did in our study. Regardless, we obtained good correlations with Pc, which is much easier to determine than kinetic energy. Figure 1 shows the Riley County data used in developing equation 4.

The soil ridge roughness factor, K, in the wind erosion equation is a function of a

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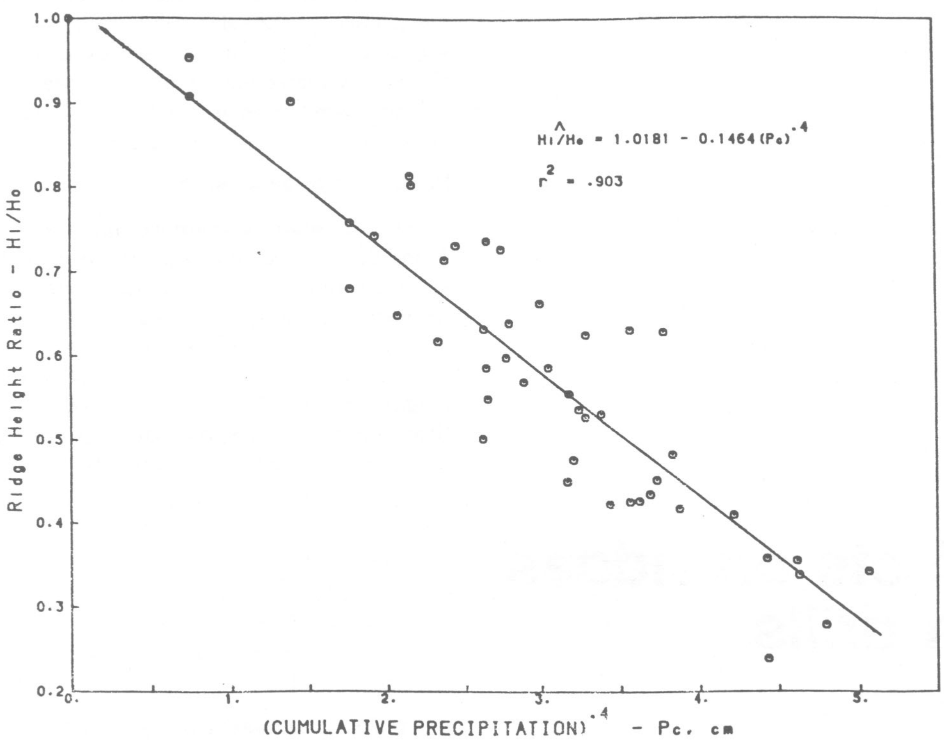

Figure 1. Changes in drill ridge heights due to precipitation, Riley County, Kansas, 1983-1986.

measure of ridge roughness, Kr (5), which is determined from the equation $Kr = 4H^2/\lambda$, [6] where H = ridge height (cm) and λ = ridge spacing (cm). From the height-spacing measurement at each site, we calculated Kr and correlated this second dependent variable with the same variables as the Hi/Ho ratio using the same regression procedures. The regression equations using data from all sites were as follows:

$$Kr = 6.9114 - 1.8167\ (Pc)^{0.333};\quad r^2 = .730 \qquad [7]$$

$$Kr = 7.9082 - 1.8341\ (Pc)^{0.333} - 21.6186\ OM/Si;\ R^2 = .781 \qquad [8]$$

$$Kr = 9.7014 - 1.8320\ (Pc)^{0.333} - 0.1955\ S/Si - 1.7163\ (OM)^{0.5};\ R^2 = .812 \qquad [9]$$

where the variables have already been defined.

Again, after separating the Riley County data alone and repeating the regression procedure, we obtained the following equations:

$$Kr = 7.1808 - 1.8657\ (Pc)^{0.333};\quad r^2 = .749 \qquad [10]$$

$$Kr = 8.3284 - 2.1097\ (Pc)^{0.3} - 0.0264\ OMC;\ R^2 = .861 \qquad [11]$$

$$Kr = 8.4415 - 1.8240\ (Pc)^{0.3} - 0.0358\ OMC - 1.7\text{x}10^{-4}\ TcS;\ R^2 = .892 \qquad [12]$$

where C = clay content (%) and Tc = cumulative time after seeding (days).

Application of the regression equations would be simplified if a relationship between ridge height and ridge spacing (row spacing) were available. Using the data obtained in this study for drills and unpublished data from Texas on listers, we developed the following simple power equation:

$$Ho = 0.329\ \lambda^{0.915};\ r^2 = .932 \qquad [13]$$

where Ho = the ridge height (cm) immediately after tillage and λ = ridge (row) spacing (cm). In the drill data, Ho varied from 3.8 to 10.2 cm and λ from 18 to 30 cm. Corresponding values for the lister data were 15 to 36 cm and 81 to 102 cm. Equation 13 should not be used at ridge spacings outside those used in its development.

A new wind erosion prediction model now under development by the Agricultural Research Service is expected to need ridge height data over time as input data when erosive windstorms occur. The following examples illustrate how to use the regression equations for estimating ridge height.

Assume a silt loam field in western Kansas has been drilled to winter wheat on September 30, using 25.4 cm row spacings. Assume 31 days have elapsed and records show 3.3 cm of cumulative precipitation. What is the ridge height now?

Step 1: Using equation 13 with λ = 25.4 cm, Ho = 6.35cm. Step 2: Using Pc = 3.3 cm in equation 4, Hi/Ho = 0.7827 or Hi = 4.97 cm, the expected ridge height after 31 days. Equation 1 could have been used in step 2, yielding Hi = 5.06 cm.

If additional data on soil properties were available, equations 2, 3, or 5 could be used in step 2. Assume the silt loam is the one located at site 41 in Ford County, Kansas (Table 1). Then, using equation 5 with sand (S) = 11.1%, silt (Si) = 63.6%, and exchangeable calcium (Ca) = 3,470 ppm, Hi = 4.80 cm.

Consider the same data with 182 days elapsed time and applying the wind erosion equation to the field in question using crop stage periods (2). Thus, the Kr value is needed to determine the soil ridge roughness factor K, one of the five factors in the wind erosion equation. Assume that cumulative precipitation (October-March) is 12.80 cm (the normal for Dodge City, Kansas). Using equations 9 and 12 with OM = 2.1%, clay (C) = 25.3%, and cumulative time (Tc) = 182 days, Kr = 2.89 cm and Kr = 2.28 cm, respectively. From Woodruff and Siddoway (5), the K value associated with a Kr of 2.28 cm is about 0.60; that compares to a value of 1.00 for a nonridged surface.

We should note that regression equations should not be used with data exceeding the

Table 1. Cumulative time and precipitation and soil data for 15 study sites across Kansas.

Site Number/ County	*Year*	*Cumulative Days*	*Cumulative Precipitation (cm)*	*Sand (%)*	*Silt (%)*	*Clay (%)*	*OM (%)*	*Exchangeable Ca (ppm)*	*Soil Series*
11/Bourbon	1984-1985	183	48.44	9.9	67.0	23.1	5.4	3,760	Zaar SiL
12/Bourbon	1984-1985	177	62.16	9.2	72.3	18.5	2.6	2,530	Catoosa SiL
21/Riley	1983-1984	186	57.47	14.4	62.4	23.2	2.4	2,600	Sutphen SiL
22/Riley	1983-1984	186	50.24	70.8	24.5	4.7	0.7	600	Carr SL
23/Riley	1983-1984	185	46.03	6.8	73.7	19.5	4.2	5,700	Smolan SiL
24/Riley	1984-1985	207	41.22	54.9	38.1	7.0	0.6	1,390	Haynie SL
25/Riley	1984-1985	180	28.70	7.9	72.1	20.0	3.1	2,570	Reading SiL
26/Riley	1985-1986	198	18.97	1.2	89.6	9.2	1.6	1,900	Eudora Si
27/Riley	1985-1986	206	27.77	1.1	72.6	26.3	2.2	4,500	Reading SiL
31/Russell	1984-1985	186	34.99	10.2	68.1	21.7	2.5	4,300	Roxbury SiL
32/Russell	1984-1985	186	34.99	15.8	60.5	23.7	2.1	3,370	Armo SiL
41/Ford	1984-1985	224	28.59	11.1	63.6	25.3	2.1	3,470	Harney SiL
42/Ford	1984-1985	181	22.02	80.9	11.0	8.1	1.1	910	Carwile LS
51/Stanton	1984-1985	221	15.11	61.0	27.6	11.4	1.2	1,210	Richfield SL
52/Stanton	1984-1985	221	15.11	88.7	6.4	4.9	0.6	800	Manter S

range that was used in developing them. All the equations become negative as cumulative precipitation increased beyond some value, indicating that the ridges have dissipated (ridge height goes to zero). For Hi/Ho or Kr values less than 0, the equations would be invalid.

Equations 1 through 5 are based on the assumption that the effect of cumulative precipitation on ridge persistence depends on the initial ridge heights (Ho). Until additional data are available, these equations should not be extended to larger ridges. For example, lister ridges are unlikely to become leveled at the rates indicated here for drill ridges.

Finally, the equations do not account for the effects of wind erosion, which could also flatten ridges created by tillage. The only sites that may have experienced wind erosion during the study period were sites 42 and 52 in western Kansas. However, no wind erosion was reported by the SCS personnel making the ridge height measurements.

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