Objective 2: Measurement and Prediction of Wind Erosion and Dust Emissions

Title: Tillage Tool Modifications for Reducing the Emission of Windblown Dust from Agricultural Soils

Personnel: Principal Investigator: Brenton Sharratt, USDA-ARS; Co-investigator: Guanglong Feng, WSU; Support staff: Bob Barry, USDA-ARS; Derek Appel, USDA-ARS; and Bruce Sauer, WSU.

Abstract of Research Findings
Alternative tillage and cropping systems are sought for reducing dust emissions and improving air quality in the Pacific Northwest dryland cropping region. The purpose of this study was to modify the conventional rodweeder that would facilitate the armouring of the soil surface with straw and large aggregates otherwise buried below the soil surface. Several modifications were tested in the laboratory; these modifications included attaching a rake or plate-rake apparatus behind the rodweeder bar. These modifications largely resulted in pushing the soil ahead of the apparatus as opposed to sieving the soil through the rake or plate-rake apparatus. These modifications were tested on a conventional rodweeder in the field. Similar results were obtained – the modifications pushed the soil ahead of the apparatus without sieving the soil. Improvements to these modifications are required that will facilitate moving (through the use of rollers or moving components) the soil from the rodweeder bar to the rake where straw and large aggregates can be separated from the finer soil material.

Objectives
Conservation tillage and cropping systems are sought in the low precipitation zone of the Columbia Plateau that will reduce windblown dust and PM$_{10}$ emissions from agricultural soils. Past studies related to tillage in the region have primarily focused on agronomic characteristics (e.g. yield, crop cover) of contrasting tillage systems and on emission characteristics of conventional tillage systems. In addition, the undercutter has been shown to be an effective primary tillage tool for reducing dust emissions during the subsequent summer fallow period. Although the undercutter represents one tool for reducing soil erodibility and dust emissions, other tillage tools are sought that can reduce dust emissions during conventional summer fallow. Therefore, the design of tillage equipment must be given some consideration in maintaining summer fallow but yet reducing soil erodibility and emissions during summer fallow.

The objectives of this research were to:
1. Modify the rodweeder, which is conventionally used to control weeds during the summer fallow phase of a winter wheat – summer fallow rotation, that will enable
armoring of the soil surface with buried crop residue and nonerodible aggregates during the rodweeding operation.

2. Determine the effectiveness of the modified rodweeder in reducing emission of windblown dust as a result of armoring the soil surface with crop residue and nonerodible aggregates in conventional summer fallow.

Methods and Materials
Our intentions for 2008 included 1) modifying the rodweeder that is conventionally used to control weeds during summer fallow in the Pacific Northwest and 2) collecting information on soil properties and dust emissions to ascertain the effectiveness of the modified rodweeder in reducing windblown dust emissions during summer fallow. Both of these objectives required concurrent planning and implementation as the effectiveness of the modified rodweeder could only be tested in soils that were in conventional summer fallow. Therefore, progress made in modifying the rodweeder and testing the rodweeder in summer fallow will be discussed separately.

Rodweeder modification
Prior to modifying a conventional rodweeder, schematics of various modifications were made from which to build prototypes. Prototypes of the intended designs were constructed in the laboratory. Schematics (and prototypes) were designed to sieve the soil during the rodweeding operation and armor the soil surface with crop residue and nonerodible aggregates that are otherwise buried in the soil mulch layer of summer fallow. A schematic of the intended design and operation of the modified rodweeder is provided in Figure 1.

![Figure 1. Schematic of intended operation of the modified rodweeder.](image)

The schematics were similar in design, some with and without the steel plate and some with various size openings of the sieve (i.e. distance between the parallel rods that constitute the sieve) as portrayed in Figure 2.
Figure 2. A schematic of the modified rodweeder. The conventional rodweeder (comprising the wheels and rod in the drawing) is modified by adding a steel plate and sieve. The arrow indicates the direction of travel.

In testing various prototypes in the laboratory, a 10 x 0.5 m wooden box was constructed and partially filled with soil. The box was 0.2 m deep and was filled to a depth of 0.1 m with air-dry Shano silt loam. Since the principle component of the rodweeder is a solid rod that is pulled through the soil at some depth (typically 0.1 m in the Columbia Plateau) during the rodweeding operation, we constructed a hand-held rodweeder that could be pulled through the soil in our wooden box. The hand-held rodweeder consisted of a handle to which is attached a steel shaft. Attached to the base of the shaft and perpendicular to the shaft was a 19-mm diameter steel rod. Smaller rods (6-mm diameter and 0.45-m long) or a steel plate (150-mm wide by 6-mm thick) were attached to the 19-mm steel rod. The small rods were mounted perpendicular to the 19-mm rod. Spacing between the small rods was 10 or 25 mm. Additional testing with the small rods included bending the rods along their length at various angles. The small rods (6-mm diameter and 0.3-m long) were also mounted along the long edge of the steel plate. One end of each small rod was welded to the plate at a spacing of 10 or 25 mm between rods. The larger rod could be attached to the shaft at various angles, thus allowing the small rods or steel plate to travel through the soil at an incline of 10 to 30°. The hand-held rodweeder (Figure 3) was pulled through the soil at 3-4 mph.

For any configuration of the hand-held rodweeder examined in the laboratory, the hand-held rodweeder pushed the soil (resulting in accumulation of soil in front of the rodweeder) as opposed to undercutting the soil. This was likely due to lack of rotation of the 19-mm rod as it was pulled through the soil. Counterclockwise rotation of the rod in a conventional rodweeder aids in moving the soil up and over the rod. Nevertheless, visual observations suggested that the
lower angle at which the assembly was pulled through the soil or wider spacing between the small rods facilitated sieving as the assembly was pulled through the soil.

The conventional rodweeder used in this study was a Calkins Model HD212-265 end-wheel drive rodweeder. The principle component of the rodweeder is a 3.6-m long solid steel rod with square dimensions (22 mm). The square rod protrudes through bushings located at the base of the shanks which are mounted to the frame of the rodweeder. The bushings and square rod rotate counterclockwise via a chain drive. The length of the square rod was reduced to 2.7 m to facilitate usage within the experimental summer fallow field plots. The rodweeder was modified by adding an attachment to the base of the shanks. The attachment was constructed to sieve soil as the soil rotated up and over the square bar. The attachment was positioned immediately behind (25 mm) and slightly below level with the square rod. Since the design of the attachment has a large impact on the sieving process, several different attachments were tested to sieve the soil. Attachments tested included 1) mounting smaller solid steel rods (6.3 mm diameter and 0.45 m long) perpendicular to a solid round steel rod (19-mm diameter) that was 2.7 m long. One end of each small rod was welded to the 2.7-m long round rod. The spacing between centers of the smaller rods was 25 mm, thus 109 small rods were equally spaced along the length of the large-diameter round rod. The sieve assembly was bolted to the shank of the rodweeder such that the large-diameter round rod maintains a slightly below level position with respect to the square rod, and 2) mounting a solid steel plate (150-mm wide by 6-mm thick) to a solid round steel rod (19-mm diameter) that was 2.7 m long. Smaller solid steel rods (6-mm diameter and 0.3 m long) were mounted perpendicular to and along the long edge of the steel plate. One end of each small rod was welded to the plate at a spacing of 25 mm between rods. The sieve assembly was bolted to the shank of the rodweeder such that the large-diameter round rod maintains a slightly below level position with respect to the square rod. In addition, the round rod could be rotated to allow the sieve assembly to travel through the soil at an incline of 10 to 30° from horizontal.

Modified rodweeder field test
The modified rodweeder was field tested at the Palouse Conservation Field Station in Pullman, Washington, on a Palouse silt loam and at the Lind Dryland Field Station in Lind, Washington, on a Shano silt loam. Our intention was to field test the modified rodweeder under various tillage practices during the summer fallow phase of a winter wheat – summer fallow rotation. These tillage practices were intended to have different quantities of wheat residue and aggregates buried in the soil mulch of summer fallow.

Tillage treatments: The experimental design was split plot with tillage as main plot treatments and rodweeder as subplot treatments. Tillage treatments will consist of both conventional and conservation tillage.

At Pullman, WA, main plots were 7.3 x 30 m while subplots were 3.6 x 30 m. Conventional tillage included: 1) mowing wheat stubble to a height of 0.1 m with a Brillion flail mower in August after harvest of 100 bushel / acre Paladin hard red winter wheat, 2) plowing in October to a depth of 0.15 m using a John Deere 4200 rollover plow, 3) cultivating twice to a depth of 0.15 m the following June using a Calkins cultivator equipped with 38 mm shanks at a spacing of 0.3 m, and 4) rodweeding monthly to a depth of 0.1 m beginning in July. Conservation tillage included: 1) mowing wheat stubble to a height of 0.1 m with a Brillion flail mower in August after harvest of 100 bushel / acre Paladin hard red winter wheat, 2) cultivating in October to a
At Lind, WA, main plots were either 14.6 x 30 m (conventional tillage) or 9.1 x 30 m (conservation tillage) while subplots were either 7.3 x 30 m (conventional tillage) or 4.5 x 30 m (conservation tillage). Conventional tillage included: 1) undercutting the soil in August to a depth of 0.13 m using a Haybuster Model 3200 Undercutter, equipped with 0.8 m wide V-blades spaced 0.7 m apart, after harvest of 40 bushel / acre Masami soft white winter wheat, 2) chiseling the soil in November prior to soil freezing to a depth of 0.25 m using a John Deere chisel plow equipped with twisted points spaced 0.3 m apart, 3) disking the soil the following May to a depth of 0.13 m using a John Deere double disk equipped with 0.56-m diameter blades, 4) and rodweeding monthly to a depth of 0.1 m beginning in May. Conservation tillage included: 1) undercutting the soil in August after harvest of 40 bushel / acre Masami soft white winter wheat and the following April to a depth of 0.13 m using a Haybuster Model 3200 Undercutter equipped with 0.8 m wide V-blades spaced 0.7 m apart and 2) rodweeding monthly to a depth of 0.1 m beginning in May.

Subplot treatments included rodweeding with either the unmodified or modified Calkins end-wheel drive rodweeder.

**Measurements:** Our intentions were to compare the erodibility of the soil following rodweeding with either the unmodified and modified rodweeder by measuring the biomass of standing and prostrate residue, stubble height and density, percent cover of residue and nonerodible aggregates, near-surface bulk density and soil water content, aggregate size distribution and stability, and surface roughness. However, due to poor performance of the modified rodweeder during initial testing in the field, measurements were not made of soil surface characteristics, crop residue properties, or dust emissions in the tillage and rodweeder experimental plots.

**Results and Discussion**

The modified rodweeder, with different sieving apparatus positioned behind the rod as portrayed in Figures 4 and 5, was tested at Pullman, WA beginning in June 2008 and later in summer 2008 at Lind, WA.

![Figure 4](image_url)  
*Figure 4. The modified rodweeder with various sieve apparatus behind the rod and attached to the shank of the rodweeder. This photo was taken during modification of the rodweeder at the Palouse Conservation Field Station in Pullman, WA.*

![Figure 5](image_url)  
*Figure 5. The modified rodweeder with various sieve apparatus attached to the shank of the rodweeder. This photo was taken at Lind, WA.*
The operation of the modified rodweeder was initially tested on a Palouse silt loam that had been in fallow two years prior to this study. The soil had been disked prior to field testing the modified rodweeder to create a dust mulch about 0.1 m deep. The soil surface was devoid of crop residue and was smooth with few large aggregates on the soil surface. Our initial test at the Palouse Conservation Field Station was not successful; the modified rodweeder did not result in transport of soil, coming over the rod, to the sieve. This is illustrated in Figure 6 where the soil can be seen pushed or heaped in front of the rod. This observation was noted for all sieve apparatus (e.g. steel plate trailing the rod with a rack of small diameter rods attached to the plate for sieving; a rack of small diameter rods, trailing the rod, for sieving) tested in this study. The Palouse silt loam is a well aggregated soil with a dispersed mean particle size of 15µm, sand content of 14%, and clay content of 18%.

We believed the performance of the modified rodweeder could be influenced by soil type as coarser soils may facilitate better transport of soil over the rod to the sieve. Therefore, the modified rodweeder was tested at the Lind Dryland Field Station in Lind, WA on a Shano silt loam; this soil is poorly aggregated with a dispersed mean particle size of 25µm, sand content of 28%, and clay content of 12%. The operation of the modified rodweeder was tested on a Shano silt loam that had been in fallow one year prior to this study. The soil had been disked prior to field testing the modified rodweeder to create a dust mulch about 0.1 m deep. The soil surface was largely devoid of crop residue and was smooth with few large aggregates on the soil surface. Similar results were observed in using the modified rodweeder on the Shano silt loam as the Palouse silt loam; the soil heaped up in front of the rod as illustrated in Figure 7.

No further modifications were made to the rodweeder as autumn rains circumvented any additional field testing in 2008. Although we believe the conventional rodweeder can be modified to armor the soil surface with crop residue and nonerodible aggregates buried within the dust mulch layer, the use of stationary plates and sieves behind the rod precluded achieving
the desired results. Therefore, advances in designing a rodweeder to accomplish our objective of armoring the soil surface with buried residue and aggregates will likely only be accomplished by the use of rotating devices behind the rod.

**Publications and Presentations**

**Refereed Journal Articles**


Sharratt, B. and G. Feng. Windblown dust emitted from conventional and undercutter tillage within the Columbia Plateau, USA. *Earth Surface Processes and Landforms* (accepted).


**Conference Proceedings**


**Published Abstracts**


