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THE RELATIVE VALUES AND METHODS OF MEASURING RESIDUES[1/]

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The subjects of this report "Relative values of residues" and "Methods of measuring residues" are related; however, each appears to be sufficiently divergent in meaning and scope to warrant separate discussions.

Part I. RELATIVE VALUES OF RESIDUES

Introduction

There are two prerequisites to a discussion of the relative values of residues. First, it is necessary to define residue and enumerate the kinds of residue under consideration. Secondly, some basis for comparing the different kinds of residue must be established. Residues are plant materials left on the surface of the ground from a previous crop. However, here residues are considered as any vegetative material above the surface of the ground and include small grain crops, sorghum, corn, legumes, and stubble from these crops — all of which are common in the Great Plains. They will be compared only on a basis of their relative value in reducing water and wind erosion. This basis of comparison does not take into account other important areas of influence such as infiltration, soil moisture, soil temperature, light and energy reflection, soil structure, chemical nature of soil, and microbial activity. However, in the interest of time and in order to make comparisons in areas where previous research has evaluated the influence of several kinds of residue simultaneously, this discussion will be confined to water and wind erosion.

Characteristics of Residues

The kind of plant from which the residue is obtained has an important bearing on its durability. Duley (5) presents an excellent discussion of some of the general characteristics of different kinds of residue. He states "Legume residues tend to decay rapidly. They contain high amounts of protein which supply nitrogen for the organisms that promote decay. However, some parts of legume plants such as the coarse stems of second-year sweetclover may be quite resistant to decay. The coarse parts of corn or sorghum stalks are quite durable, especially if they are on top of the soil. When partly buried so that they remain damp for a considerable time, they may decay rapidly. Wheat and rye straw are more resistant to decay than oats straw."

The extent of decay at the time when the residue is exerting its influence on a given process largely determines its effectiveness.

Relative Values of Residue for Water Erosion Control

Considerable evidence is found in the literature to show that if land is covered with crop residue — any kind of vegetative matter anchored to the soil surface — runoff and erosion will be reduced. Far less information is available on the relative effects of different kinds of residues. Since residues reduce erosion and runoff by protecting the soil from the beating action of the raindrops and by acting as small dams to hold the water in small ponds, it follows that they are generally more effective if they are of a nature and of such quantity to provide a complete persistent cover. Van Doren and Stauffer (11), after evaluating the effectiveness of soybean, cornstalk, and wheat straw residues for reducing runoff and erosion concluded that wheat straw was particularly effective, and that cornstalks provided greater bulk and more complete surface coverage than soybeans and were therefore more effective in reducing erosion. Their data from a 120-minute test of simulated rainfall showed that 62 percent of the water applied ran off from soybean plots as compared with only 26 percent for corn plots.

In most research on water erosion and in the development of the universal soil-loss equation, the effect of residues has been evaluated in terms of a cropping-management factor. This factor evaluates the effect of quantity and quality of crop cover, root growth, and water use by growing plants, as well as the effect of prior-crop residues. It is expressed in terms of the expected ratio of soil loss from land cropped under specified conditions to corresponding soil loss from continuous fallow on identical soil and slope and under the same rainfall (12). Because of the many factors included in this index it is difficult to isolate the effect of prior-crop residue. Table 1 does show, however, a few values taken from Wischmeier's table for his so-called "4th period of crop stage growth", which is designated as from crop harvest to turn plow or new seedbed.

In summary, the relative values of different kinds of residues for water erosion control in order of effectiveness would be: Well-established legume meadows > wheat stubble > cornstalks first year after meadow > well-established growing wheat > cornstalks on continuous corn equal to soybeans and sorghums > growing wheat 0 to 2 months after planting if prior crop residues left on surface > cotton > growing wheat 0 to 2 months after planting on plowed land.

Relative Values of Residues for Wind Erosion Control

The principal function of crop residues when used to control wind erosion is to decrease the force of the wind on the soil surface. Several factors in addition to kind and weight of residue are important in wind erosion control. Zingg et al. (13) indicated that density, height, and orientation of the residues at the surface of the soil are important. Pound for pound, the finer the residue the more protection it gives to the soil provided it is equally distributed and anchored. Residue in a flat position and long or tall residue or stubble is more effective than an equal weight of short residue. The amount of leaves on stubble is also important in increasing density of stubble. All of these points are well illustrated by results of some recent research by Siddoway3/. Table 2A shows the effect of orientation and Table 2B shows the effect of density.

Table 1.--Ratios of soil loss from 4th period of crop growth1/ to corresponding loss from continuous fallow2/.

Kind of residue	Ratio
	%
Cornstalks	
Continuous corn - 75 bu./acre yield.	30
First year corn after meadow - 75 bu./acre yield.	15
Wheat	
Stubble and straw	10
Growing plants - 0 to 2 months after planting on land cropped to wheat for three or more years with residue plowed under.	55
Growing plants - 0 to 2 months after planting on land cropped to wheat for three or more years with residue left on surface.	40
Growing wheat - 2 months after planting to harvest on land cropped to wheat 3 or more years with residue left on surface.	20
Legumes	
Established meadows:	
Sweetclover - 2 tons/acre yield.	2
Grass legume mix - 1 to 2 tons/acre yield.	0.6
Soybeans - cultivated.	30
Sorghums	
Continuous sorghum.	30
Cotton	
Continuous, without winter cover.	48

1/ Except for growing wheat where data for periods 2 and 3 are given.
2/ Data from Wischmeier (12).

Zingg et al. (14) using a portable wind tunnel also made some field investigations of the effect of sorghum row orientation with respect

3/ Unpublished data from F. H. Siddoway.

to wind direction. They showed that when sorghum stubble rows were transverse to the wind the relative velocity, drag on the soil surface, and erosion were decreased. Using prevailing wind direction data for Dodge City, Kansas, where 80 percent of the winds come from north-south, they showed soil losses from sorghum rows drilled east-west to be about one-half those from rows drilled north-south.

Table 2A.--Effect of residue orientation[1/].

Kind of residue	Orientation	Wind tunnel erodibility I_w (Dimensionless)
Wheat stubble (500 lbs./acre)	Standing	6
	Leaning	80
	Flattened	450
Growing wheat plants (500 lbs./acre)	Wind perpendicular to rows	4
	Wind parallel with rows	25

Table 2B.--Effect of density of residue[2/].

Kind and density of residue	Wind tunnel erodibility I_w (Dimensionless)
3000 lbs./acre wheat stubble	4
3000 lbs./acre fine sorghum stubble	175
3000 lbs./acre coarse sorghum stubble	500

1/ Unpublished data from F. H. Siddoway.
2/ Unpublished data from F. H. Siddoway.

Chepil[4/] in recent revision of the wind erosion equation and of methods of estimating erodibility of fields has utilized the Siddoway data and those of previous research (3, 4) to devise a method of expressing the total effect of residue in terms of the equivalent quantity of vegetative cover, V. V is equal to the product of the quantity of residue, R, times the kind of vegetative matter factor, S, times the orientation of vegetative cover factor K_o, which in effect is the vegetative surface roughness factor. S denotes total cross-sectional surface area. The finer the material, the greater its surface area, the more it slows the wind and reduces erosion.

Chepil has developed curves of R versus K_o for growing small grain crops, for standing and flattened anchored small grain stubble, and for flat and 8-, 12-, 16-, and 20-inch standing sorghum stubble.

4/ Unpublished data from W. S. Chepil.

The values of S for different kinds of vegetative residue above the surface of the ground are given in table 3.

Table 3.--Values of S for different kinds of vegetation[1].

Kind of vegetation	Factor S
Small grain stubble and stover	1.00
Sorghum stubble and stover	0.25
Corn stubble and stover	0.20
Small grain in development stage, dead or alive	2.50

1/ Unpublished data from W. S. Chepil and F. H. Siddoway.

Since wind erodibility, E, and the equivalent quantity of vegetative cover, V, are related so that the larger V then the smaller E, values of V equal to R times S times K_o can be used to determine the relative effectiveness of the different kinds of residue. Table 4 presents these results using 1000 lbs./acre of each of the indicated kinds of residue on a soil having an average annual erodibility I, when not protected by vegetative cover, equal to 86 tons per acre.

Table 4.--Relative effectiveness of 1000 pounds per acre of different kinds and orientations of residue to control wind erosion E[1]

Kind and orientation of residue	S_o	K_o	R	V	I	E
					Tons/A.	Tons/A.
Standing small grain stubble	1.0	8.8	1000	8800	86	2.8
Flattened small grain stubble	1.0	3.4	1000	3400	86	35.0
Flattened sorghum	0.25	2.7	1000	675	86	75.0
12-inch standing sorghum	0.25	4.0	1000	1000	86	68.0
Growing wheat plants	2.50	3.4	1000	8500	86	3.2

1/ Unpublished data from W. S. Chepil and F. H. Siddoway.

In summary, the relative values of different kinds of residues for wind erosion control in order of effectiveness are standing small grain stubble > growing wheat plants > flattened small grain stubble > 12-inch standing sorghum > flattened sorghum of any length.

Part II. METHODS OF MEASURING RESIDUES

Introduction

Residue measurements are required in research on effectiveness of stubble mulching, in evaluations of effects of tillage machinery, and in evaluations of conservation practices on farms in connection with ACP payments.

Amounts of crop residue have been determined by both visual estimations and actual measurements. Visual estimations are usually accomplished with the aid of some device such as a photograph. Actual measurements of crop residues have generally been made by picking up the residues by hand and weighing.

There has been no standard method of measuring residues. Procedures for taking, cleaning, weighing, and reporting data have varied widely. Lack of such a standard has, as McCalla and Army (10) pointed out in their recent review of stubble mulch farming, "...probably resulted in a considerable amount of confusion and misinterpretation of results."

Part II of this report will include a discussion of the two methods of determining residue amount and a recently proposed standardized procedure for residue sampling.

Estimating

Three methods that have been used or proposed in the past to estimate surface residues are: (1) using photographs as visual guides; (2) using the point quadrate method wherein residues are measured by determining their relationship to a point or points; and (3) measuring light reflection from residue-covered surfaces.

McCalla (9), in a study designed to measure the light reflection from stubble mulch, demonstrated that different amounts of light were reflected from different quantities of dark and bright straw. He was able to measure substantial differences in reflection between straw amounts of 1/10, 1/4, and 1/2 ton per acre but when tests were made on straw amounts of 1, 2, and 4 tons per acre, differences in reflected light were so small that it would be nearly impossible to distinguish between them.

Duley (5) proposed a photographic method of estimating residue amounts. He used a standard set of 33 pictures depicting different amounts of various crop residues. The procedure for using the method was to match a photograph showing a known amount of residue with the field in question. Chepil and Woodruff (4) also used a set of 18 photographs of different field surfaces primarily to estimate surface roughness for computing wind erodibility of farm fields. Residue amounts were also given for each photograph and it was suggested, although not recommended, that the photographs could be used to estimate residues in the absence of actual measurements.

The point method seems to have evolved from the thinking of a quadrant, which becomes smaller and smaller until it is a point. Brown (2), Levy (6), Levy and Madden (7), and Cockayne (2) all used some sort of a point method, varying from Levy's knots on a tightly stretched string to Cockayne's toe cap of a boot. More recently, Mannering, as reported by Brown[5/], made an adaptation of the point method by driving 100 shingle nails in a 1-inch grid pattern in a piece of plastic 1 foot square. The device is used by placing it on the residue to be measured and then counting all of the nails that touch or point directly toward residue. Cover is expressed in terms of a percentage. A table is provided giving percent cover for different tons per acre of wheat straw. Brown checked the device by preparing wooden trays of different amounts of straw uniformly fixed. He found the greatest accuracy for rates of one ton or less.

Measuring

Actual measurements of surface residues have all been made in generally the same way, i.e., gathering up the residue, weighing, and expressing in tons or pounds per acre. The procedure for doing this has, however, varied widely. Publications by McCalla, Duley, and Gooding (8), Chepil and Woodruff (4), and Anderson (1) have presented methods for measuring crop residue. In addition, many other individuals have devised their own procedures.

Areas to be sampled have been marked off with 3-sided folding and 4-sided non-folding frames with a center pin and string to circumscribe a circular area and with simple linear measurement down the row. The frames have been both rigid and adjustable. They have been oriented randomly, across 1 row, across 2 rows or more, and at 45° angles to the row direction.

Some typical sizes of sampling areas reported in literature and correspondence are: 1-square meter, 1-square yard, 1-square foot, 1 foot by 5 feet, 3.5 feet by 6.5 feet, and 3 feet by 7 feet.

The number of samples taken has varied from 1 to 25. The number taken has not always been determined on a sound statistical basis but on an individual judgment basis.

In actually gathering residues, two methods have been used in connection with erosion studies. In one, only the surface residues were taken. In the other, they were taken to a 1-inch depth.

Weed growths have been sampled and included as total residue, ignored, or sampled and reported separately. The same is true for animal manures. Crowns also have or have not been included. The general consensus of opinion seems to be that crowns do not have much influence on wind erosion, but are important for water erosion control.

Shaking the residue sample in a potato sack, rubbing the soil through a screen, fanning, and washing are some of the procedures used to clean residue samples.

5/ Brown, P. L. Device for measuring surface residues. Mimeographed report prepared for Stubble Mulch Workshop, November 14-16, 1961, Fort Collins, Colo.

The samples have been oven-dried, air-dried, and weighed directly from the field at ambient air conditions.

Opinions on the required accuracy of weighing vary. Samples have been weighed to the nearest 1/100 of a pound and 1/10 of a gram and reported to the nearest 1/10 of a pound per acre. Others feel that such accuracy is not warranted and recommend that weights be reported to the nearest 200 or 500 pounds per acre.

All of this evident variation in methods of measuring residue points to a need for a standardized procedure. This need was recognized in 1960 by the Western Branch of the Soil and Water Conservation Research Division of the Agricultural Research Service and a committee was appointed to draw up some standardized procedures[6/]. These procedures have now been revised after reviews by many individuals throughout the country, and will be published in the near future. It is hoped that if future measurements of residue are made in accordance with this standard, much of the confusion that may have led to misinterpretation of results in the past can be avoided.

6/ Standardized procedure for residue sampling. Report of Committee. Dr. C. J. Whitfield, Chairman. Committee members: J. J. Bond, E. Burnett, W. S. Chepil, B. W. Greb, T. M. McCalla, J. S. Robins, F. H. Siddoway, R. M. Smith, and N. P. Woodruff.

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