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ABSTRACT

The wind erosion equation, which estimates annual potential erosion, requires that all vegetation (dry weight per area) be expressed as a small grain equivalent (SG)e. Wind-tunnel tests were used to determine that equivalent for five growing crops. These are corn (*Zea mays* L.), cotton (*Gossypium hirsutum* L.), grain sorghum [*Sorghum bicolor* (L.) Moench], peanuts (*Arachis hypogaea* L.), and soybean [*Glycine max* (L.) Merr.] in rows both perpendicular and parallel to flow. Compared with the small grain standard, all the growing crops evaluated in rows perpendicular to flow effectively prevented erosion. Because measured or estimated amounts of aboveground biomass are needed in determining (SG)es, simple power equations relating biomass to plant height were developed. For short-term application of the wind erosion equation by crop stage period or in models with daily time steps, an equation was derived for calculating (SG)e from time-after-emergence growth curves.

Additional index words: **Small grain equivalent, Wind erosion equation, Wind erosion control, Erosion models.**

An important principle of wind erosion control is establishing or maintaining vegetative cover (17). The quantity, kind, and areal distribution and orientation relative to the wind direction and soil surface determine the degree of protection provided by vegetation (3, 7, 14). In using the wind erosion equation for evaluating or designing management systems for wind erosion control, all vegetative cover (dry weight per unit area) must be expressed in terms of its equivalent to a small grain standard (SG)e (8, 18).

Equivalents data are available for several range grasses and agronomic crops (8, 9). Except for small grain [actually winter wheat (*Triticum aestivum* L.)], all previous equivalents data have been limited to the dead residue crop stage or the dormant grass stage. Procedures for applying the wind erosion equation by crop stage period (2) and the daily time step of the EPIC model (16) require data for growing vegetation (crops). We initiated this study to determine the small grain equivalent of selected growing crops, especially those considered in the EPIC model.

MATERIALS AND METHODS

Corn (*Zea mays* L.), cotton (*Gossypium hirsutum* L.), grain sorghum [*Sorghum bicolor* (L.) Moench], peanut (*Arachis hypogaea.* L.), and soybean [*Glycine max* (L.) Merr.] plants were tested at four normal heights (Table 1) and four plant populations (165 522, 121 970, 87 120, and 52 272 plants/ha plus 69 695 and 34 847 plants/ha for cotton) in a wind tunnel in 76-cm rows both perpendicular and parallel to airflow direction. The laboratory wind tunnel, 1.52 m wide, 1.93 m high, and 16.46 m long, was a recirculating push-type with airflow generated by a 10-blade variable-pitch axivane fan.

The plants were grown in the greenhouse in a rectangular container 1.2 by 1.2 by 9.1 m in a 1:1:1 mixture of topsoil, peatmoss, and perlite. Before testing, plants were pulled from the container and the roots placed in wax-coated cartons of water to maintain turgidity. Plants were held in place in the cartons by 5-cm thick foam blocks. The appropriate kind, height, and population of plant was placed in standard test trays 148 cm long, 16.5 cm wide, and 4 cm deep. For the parallel-to-flow case, one of the trays was wider (37.8 cm). Plants were pulled from the greenhouse container and anchored within the trays; the trays were filled with dry, erodible sand 0.297 to 0.42 mm in diameter. Plants on the trays were changed after each run.

Two test trays (test area) were located approximately 14.5 m downwind and 0.07 m apart (side by side) during each exposure to wind. The entire wind-tunnel floor area downwind and 7.6 m upwind from the test area (trays) contained the same height and population of plants as the test trays using plants in wax cartons. The trays were exposed for 5 min at 13.36 m/s freestream windspeed in the tunnel. The sand loss was determined from the difference in tray plus sand weight before and after exposure to wind. Generally, three replications (six test trays) of each crop condition were tested to establish the relationship between sand loss rate and the dry weight per unit area (biomass) of each crop.

Winter wheat stubble, displayed in the reference manner, was tested under the same conditions as the other growing crops to provide the comparison required for determining small grain equivalents. This reference condition (standard) is defined as 25.4 cm of dry small grain stalks lying flat on the soil surface in rows perpendicular to wind direction with 25.4-cm row spacing, with stalk oriented parallel to the wind direction (18).

RESULTS

Figure 1 shows a typical curve of sand loss rate as related to the amounts of dry vegetation for growing grain sorghum in rows perpendicular to flow and winter wheat stubble in the reference orientation. These and similar data for the other crops were converted to an equivalent quantity of flat small grain residue (Fig. 2). Corresponding data for corn, cotton, and soybean in rows parallel to flow are given in Fig. 3. No relationship from the data could be determined for grain sorghum and peanuts in rows parallel to flow.

A power equation of the form

$$(SG)e = a_1 R_w^{b_1} \qquad [1]$$

correlated the data well, as evidenced by high simple correlation coefficients (r). In the equation, (SG)e is the small grain equivalent and R_w is the aboveground dry weight of the crop to be converted, both in kilograms per hectare; and a_1 and b_1 are constants. Specific values for the constants for each crop and row orientation to flow, along with the corresponding r^2, are given in Table 2.

DISCUSSION

Because greenhouse-grown plants usually have lower total leaf area and higher water contents than field-grown plants of equal height, we adjusted the dry weights of our greenhouse plants to be equivalent to plants of the same height as ones in the field where

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Table 1. Physical data of various crops tested (greenhouse plants).

Crop	Variety	Height	Dry weight per plant	Basal stem diameter†	Leaf area per plant
		cm	g	cm	cm^2
Corn	Fontanelle 635	8.5 ± 1.4	0.04 ± 0.01	0.28 ± 0.03	17.9 ± 3.1
		13.3 ± 2.6	0.08 ± 0.01	0.34 ± 0.02	30.9 ± 7.0
		26.6 ± 2.1	0.36 ± 0.05	0.50 ± 0.04	106.5 ± 21.5
		49.1 ± 4.1	1.76 ± 0.37	0.96 ± 0.10	542.6 ± 90.9
Cotton	Dunn 120	8.3 ± 1.3	0.15 ± 0.03	0.32 ± 0.06	34.7 ± 7.6
		11.2 ± 1.7	0.31 ± 0.04	0.33 ± 0.02	52.0 ± 6.0
		25.9 ± 2.2	1.58 ± 0.24	0.47 ± 0.04	231.7 ± 30.5
		43.2 ± 2.2	4.32 ± 0.61	0.60 ± 0.04	469.0 ± 61.1
Grain sorghum	RS 626	6.6 ± 1.2	0.01 ± 0.01	0.17 ± 0.02	4.5 ± 1.2
		13.0 ± 2.5	0.06 ± 0.01	0.28 ± 0.02	22.8 ± 6.7
		26.3 ± 2.2	0.34 ± 0.04	0.52 ± 0.04	118.9 ± 22.1
		43.6 ± 3.9	1.36 ± 0.35	0.81 ± 0.08	322.6 ± 36.8
Peanut	Sunbelt runner	7.1 ± 0.8	0.25 ± 0.05	0.36 ± 0.03	56.8 ± 12.6
		12.7 ± 1.0	0.58 ± 0.10	0.39 ± 0.04	98.9 ± 21.4
		23.3 ± 2.2	1.37 ± 0.35	0.40 ± 0.04	155.6 ± 42.8
		27.2 ± 2.2	4.20 ± 0.65	0.49 ± 0.04	289.4 ± 56.1
Soybean	Williams	6.9 ± 1.1	0.07 ± 0.01	0.26 ± 0.03	12.6 ± 3.4
		12.6 ± 1.0	0.20 ± 0.03	0.27 ± 0.02	56.4 ± 11.5
		24.1 ± 1.9	0.56 ± 0.15	0.28 ± 0.03	208.7 ± 49.2
		45.1 ± 5.5	0.99 ± 0.25	0.29 ± 0.03	418.3 ± 103.6

† Average of wide and narrow stem diameter below the first leaf or petiole.

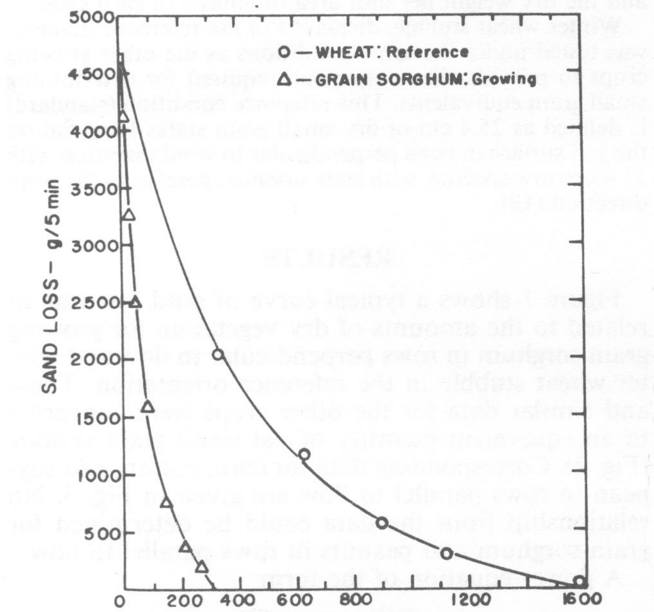

Fig. 1. Wind-tunnel sand loss as related to amount of growing grain sorghum. Winter wheat is in the reference orientation.

adequate field data were found. For corn and grain sorghum, we obtained field data from the same varieties grown at the Kansas State University Ashland Agronomy Farm. We used average data of seven soybean varieties grown in Central Iowa (5) and four peanut cultivars grown in Florida (4). Cotton field data was obtained (D.F. Wanjura, Lubbock, TX, 1983, unpublished data).

Except for soybeans, Fig. 2 indicates that differences in (SG)e among crops for amounts between 30 to 100 kg/ha are less than 20% from those computed from an average equation determined from pooling all the crop data. Consequently, if only rough estimates of the (SG)e are needed, then the average coefficients in Table 2 could be used. Also, if (SG)e values for untested grow-

Table 2. Coefficients for prediction equation: (SG)e = a$_1$ $R_w^{b_1}$ (Eq. [1]) by crop and row orientation to flow. (SG)e is the small grain equivalent and R_w is the dry weight of the crop to be converted, both in kg/ha.

Prediction equation coefficients	Growing crop					
	Corn	Cotton	Grain sorghum	Peanut	Soybean	Avg
Row perpendicular to flow:						
a$_1$	11.171	10.584	3.612	6.537	19.244	8.871
b$_1$	0.788	0.830	1.068	0.984	0.813	0.885
r^2	0.993	0.993	0.999	0.994	0.994	0.995
Row parallel to flow:						
a$_1$	0.071	5.696	†	†	8.525	--
b$_1$	1.379	0.721	--	--	0.772	--
r^2	0.992	0.987	--	--	0.996	--

† No relationship could be determined from data.

Table 3. Coefficients for prediction equation: W_d = a$_2$ h^{b_2} (Eq. [2]) for selected growing crops. W_d is dry weight in g/plant and h is plant height in cm.

Crop	Prediction equation coefficients a$_2$	b$_2$	r^2
Corn	0.0003	2.496	0.977
Cotton	0.0054	2.071	0.987
Grain sorghum	0.0004	2.192	0.995
Peanuts†	0.0054	1.886	0.915
Soybean	0.0017	1.932	0.988

† Greenhouse plants; all others are for field grown plants.

ing crops are required, then the average equation might be used. We should note here that all the crops tested in rows perpendicular to flow are considerably superior to the flat small grain standard in protecting against wind erosion (Fig. 2).

Because of single direction flows in the wind tunnel, crops in rows parallel to flow are considered to give less erosion protection than in atmospheric winds where short-term deviations of 10 to 15 degrees from the mean are common. For grain sorghum and peanuts, adding larger amounts of biomass by increasing plant population or height did not reduce sand loss from the test trays. In some cases there was a slight increase in sand loss with taller plants because the wind-tunnel flow was channeled between the rows. Consequently, the data in Fig. 3 are not a good estimate of how these growing crops will protect in the field when mean wind direction is parallel with row direction. The data are more highly correlated for cotton and soybean, both broadleaved plants, because their leaves do not *streamline* with the flow to the same degree as crops like corn and grain sorghum, whose leaves tend to line up in the flow direction when exposed to strong winds. However, these data illustrate the well-established fact that the same amount of crop biomass in rows perpendicular to flow is far superior to that in rows parallel to flow. In our wind tunnel tests of 200 kg/ha dry weight, corn in parallel rows was only 15% as effective as corn in perpendicular rows. Corresponding values were 30% for cotton and 36% for soybean.

To use the small grain equivalents data, amounts of growing biomass for each crop at a given time are needed. Other methods besides harvesting, drying, and weighing for estimating aboveground biomass for var-

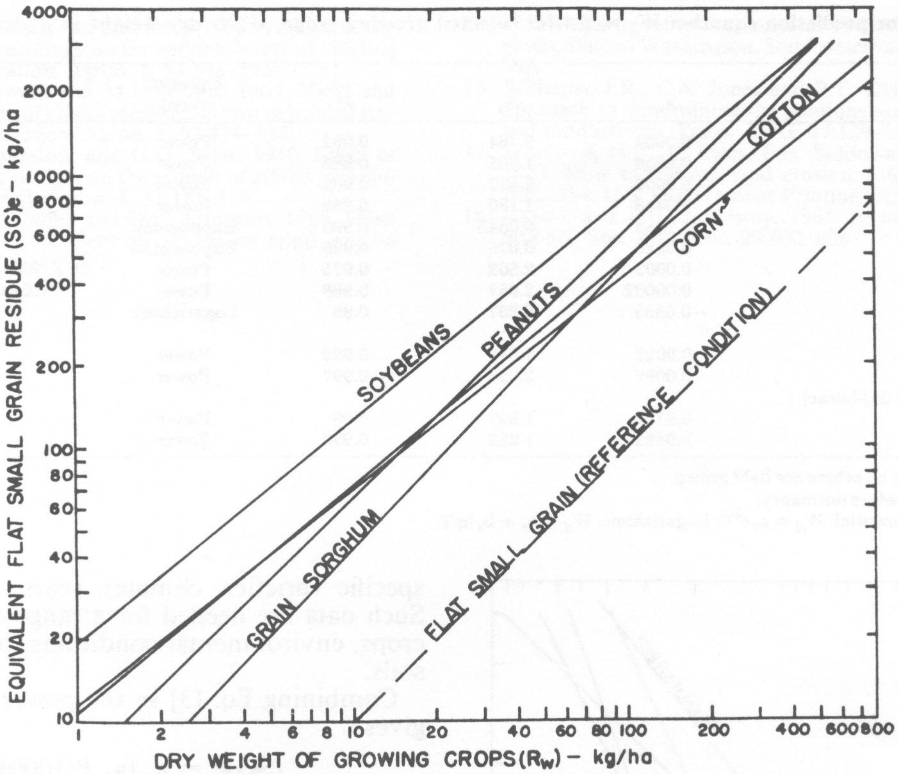

Fig. 2. Converting growing corn, cotton, grain sorghum, peanut, and soybean in rows perpendicular to flow to quantity of equivalent flat, small grain residue. Prediction equation coefficients are given in Table 2.

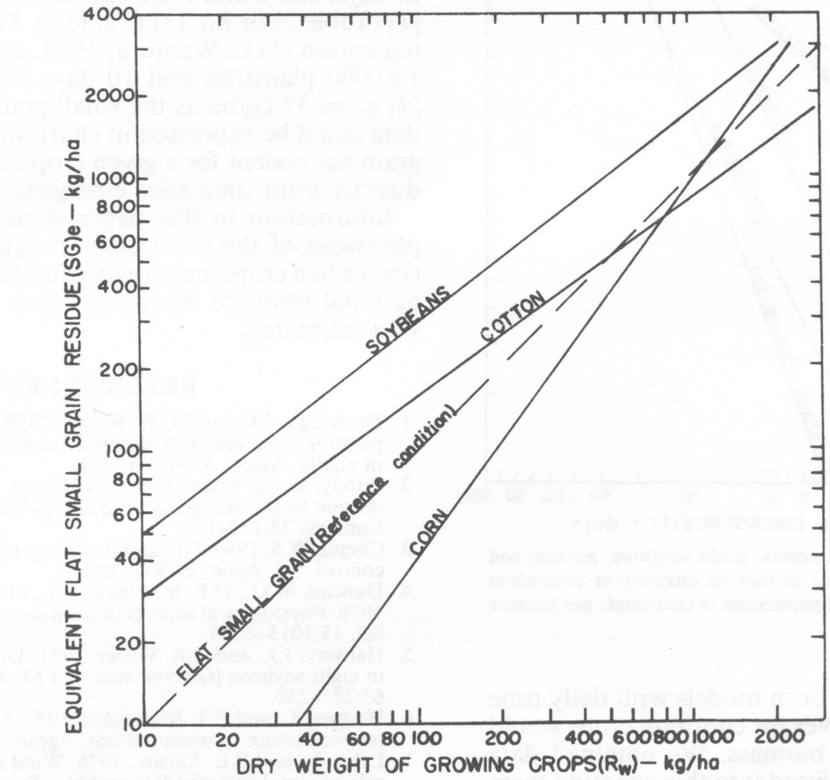

Fig. 3. Converting growing corn, cotton, and soybean in rows parallel to flow to quantity of equivalent flat, small grain residue. Prediction equation coefficients are given in Table 2.

ious crops would be convenient. We found that basal stem diameter, leaf area, and height were all good predictors of dry weight per plant. Because of ease of measurement, we chose plant height and this simple power equation to estimate plant weight (Table 3).

$$W_d = a_2\, h^{b_2} \qquad [2]$$

where W_d is dry weight in g/plant, h is plant height in cm, and a_2 and b_2 are constants.

For short-term application of the wind erosion equa-

Table 4. Coefficients for prediction equation W_d = f(t) for selected growing crops. W_d is dry weight in g/plant and t is time after emergence in days.

Crop	a_3	b_3	r^2	Equation type§	Source
Corn†	0.0009	2.764	0.997	Power	This study
Cotton†	0.0038	1.865	0.986	Power	This study
Grain sorghum	0.0002	2.577	0.982	Power	This study
Peanut†	0.0448	1.180	0.988	Power	This study
Peanut	0.2653	0.0845	0.996	Exponential	(4)
Soybean	0.0540	0.075	0.998	Exponential	(5)
Cotton	0.0002	2.502	0.975	Power	D. F. Wanjura, 1983 (unpublished)
Cotton	0.00002	2.957	0.988	Power	Bilbro, 1965 (unpublished)
Alfalfa (*Medicago sativa* L.)	−0.6633	0.237	0.95	Logarithmic	(1, 11, 13)
Alfalfa (regrowth)	0.0022	1.536	0.992	Power	(12)
Pearl millet [*Pennisetum americanum* (L.) Leeke]	0.0092	2.258	0.997	Power	(10)
Winter wheat‡	0.8784	1.627	0.96	Power	(6)
Winter wheat‡	3.0422	1.252	0.996	Power	(15)

† Greenhouse grown plants; all others are field grown.
‡ W_d is kg/ha, and growth before dormancy.
§ Power: $W_d = a_3 T^{b_3}$; Exponential: $W_d = a_3 e^{b_3 t}$; Logarithmic: $W_d = a_3 + b_3 \ln T$.

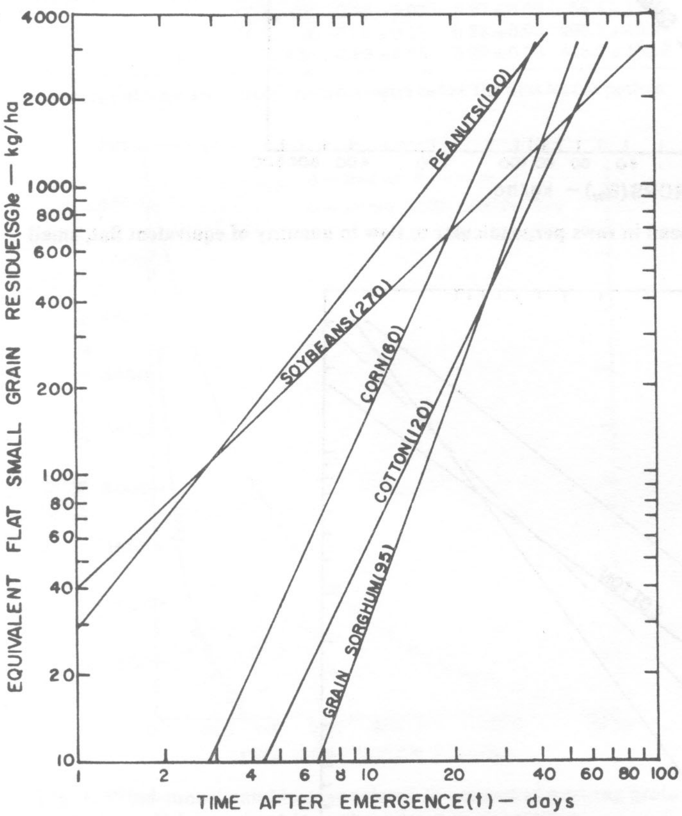

Fig. 4. Converting growing corn, cotton, grain sorghum, peanut, and soybean in rows perpendicular to flow to quantity of equivalent flat, small grain residue. Plant population in thousands per hectare is given in parenthesis.

tion by crop stage-period or in models with daily time steps, average growth curves for common crops would be useful for estimating biomass. We obtained data from several sources and fitted it to this equation form

$$W_d = f(t) \qquad [3]$$

where W_d is dry weight in g/plant and t is time after emergence in days. The equations that best fitted the data were of the power, exponential, or logarithmic type (Table 4). The data in Table 4 were derived from specific varieties, climates, years, and management. Such data are needed for a range of varieties within crops, environmental conditions, planting dates, and soils.

Combining Eq. [3] in the power form and Eq. [1] gives

$$(SG)e = a_1\,(a_3\,P/1000)^{b_1}\,t^{b_1 b_3} \qquad [4]$$

where P is plants per hectare, t is time after emergence in days, and a and b are constants associated with Eq. [1] (Table 2) or Eq. [3] (Table 4). For example, choosing cotton (D.F. Wanjura, 1983, unpublished data) at 120 000 plants/ha and 10 days after emergence, Eq. [4] gives 57 kg/ha as the small grain equivalent. Such data could be expressed in chart form where the small grain equivalent for a given crop could be determined directly from time after emergence (Fig. 4).

Information in this paper should be useful in applications of the wind erosion equation for time periods when crops are growing and for improving future national resource inventories that involve wind erosion estimates.

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