A NEW METHOD TO PREDICT SEED YIELD OF MOIST-SOIL PLANTS

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Abstract: Multiple linear regression can be used to predict seed yield of moist-soil plants; however, measurement of multiple predictor variables is tedious, subject to variation, and these models can exhibit multicollinearity. Thus, we tested if simple linear regression models could predict seed yield of 5 species of moist-soil plants as precisely as multiple linear regression models. The single predictor variable was number of dots on a grid covered by seed. Simple regression models explained as much variation in seed mass (R^2_{adj} = 0.92–0.97) and predicted (R^2_{pred} = 0.91–0.96) as well as or better than multiple regression models. Precision of models was attributed to the strong positive linear relation between the dependent variable and the predictor, accurate dot counting, and lack of multicollinearity. Dot counting also was easier and more efficient than measuring multiple phytomorphological variables. This new method is useful for researchers and managers estimating seed yield of moist-soil plants; however, additional models should be developed for other plant species, and the method should be tested in other regions.

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Laubhan and Fredrickson (1992), Gray et al. (1999*a*), and Sherfy and Kirkpatrick (1999) developed multiple regression models to predict species-specific seed yield of moist-soil plants by using phytomorphological variables. Measurement of several explanatory variables and use of multiple regression models to predict seed yield of moist-soil plants may be unnecessarily complex. Thus, we tested if a single and efficiently measured variable (i.e., number of dots on a grid obscured by seed) would precisely predict seed yield of several common moist-soil plants.

STUDY AREA

The field segment of our study was conducted in October 1994 at Noxubee National Wildlife Refuge (NNWR), Mississippi (Wehrle et al. 1995). The specific study site was an 80-ha moist-soil management complex composed of 11 impoundments. Plants were collected from impoundments 5a and 7 in the complex. Management of the NNWR moist-soil management complex has been described (Gray et al. 1999*a,b*).

METHODS

Vegetation Sampling and Measurements

We randomly established 30 1-m^2 plots in impoundments 5a and 7 (15 plots/impoundment). One plant with a visibly mature and intact seed head was randomly collected per plot for each of the following species (n = 30 plants/species): (1) common barnyardgrass (*Echinochloa crus-galli*), (2) fall panicum (*Panicum dichotomiflorum*), (3) panic grass (*Panicum agrostoides*), (4) beakrush (*Rhynchospora globularis*), and (5) green bristlegrass (*Setaria viridis*). These plant species were selected because they produce seeds used by waterfowl (Reinecke et al. 1989), and they were species for which multiple regression models had been developed to predict seed yield (Laubhan and Fredrickson 1992, Gray et al. 1999*a*).

Inflorescences of plants were clipped, transported to a lab, and placed in a plant press (Wobeser et al. 1980:548–549) with pedicels spread apart to avoid overlapping seeds. We stored inflorescences at room temperature in the press for 7 days. After this period, we laid each inflorescence on a dot grid (9 dots/cm^2)

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attached to a board and counted the number of dots partially or completely obscured by seed or seed parts (Gray 1995:137). Number of obscured dots per inflorescence were summed across multiple inflorescences of a plant. We did not count dots obscured by stems.

Seeds were threshed from inflorescences, dried, and weighed following Laubhan and Fredrickson (1992). Awns and bristles associated with seeds of beakrush and green bristlegrass were not removed before counting dots and weighing seeds, because it was difficult to extract these parts without damaging seeds. Thus, estimates of seed mass for these 2 species may be slightly positively biased.

Statistical Analysis

We used simple linear regression to develop species-specific models (Myers 1990:8). Seed mass per plant (dependent variable [Y]) was regressed against number of dots obscured per plant. We tested and corrected residual normality and homoscedasticity via the same methodology as Gray et al. (1999*a*), except for correction of heteroscedastic errors. A variance-equalizing transformation was performed if residuals were heteroscedastic (Bowerman and O'Connell 1993:226). We also corrected for randomness of the predictor variable following Mandel (1984). Adjusted (R^2_{adj}) and predicted (R^2_{pred}) coefficients of determination were computed to reflect model precision and predictive ability (Myers 1990:166, 171).

RESULTS

Violations of residual normality in fall panicum and green bristlegrass and homoscedasticity in common barnyardgrass and panic grass were corrected before model development. All regressions of seed mass per plant against number of dots obscured were positive and significant ($P < 0.001$; Table 1). Additionally, all models exhibited high precision ($R^2_{adj} = 0.92–0.97$) and predictiveness ($R^2_{pred} = 0.91–0.96$; Table 1).

DISCUSSION

Our simple regression models explained variation in seed mass of moist-soil plants and predicted as well or better than multiple regression models (Laubhan and Fredrickson 1992, Gray et al. 1999*a*). We attributed enhanced precision and predictiveness to the strong positive linear relation between seed mass and number of ob-

Table 1. Regression equations and statistics for estimating dry seed mass (g) of 5 moist-soil plants via the number of dots obscured by seed (DOTS), Noxubee National Wildlife Refuge, Mississippi, 1994.

Plant species	n[c]	Equation[a] (Y = g seed/plant)	F[d]	R^2_{adj}	g seed/plant[b] Minimum	Maximum
Common barnyardgrass[e]	30	$[(0.025037/\text{DOTS}) + 0.003177] \times \text{DOTS}$	302.57	0.953	0.288	2.477
Fall panicum	28	$-0.121729 + (0.001033 \times \text{DOTS})$	916.48	0.972	0.135	1.359
Panic grass[e]	30	$[(-0.035515/\text{DOTS}) + 0.001047] \times \text{DOTS}$	289.50	0.951	0.157	1.042
Beakrush	30	$-0.063391 + (0.003473 \times \text{DOTS})$	762.65	0.964	0.257	2.285
Green bristlegrass	29	$-0.008450 + (0.003288 \times \text{DOTS})$	317.78	0.920	0.060	0.448

[a] All equations were corrected for the random predictor variable (Mandel 1984).
[b] Model performance beyond these ranges is unknown.
[c] Sample size was <30 for fall panicum and green bristlegrass because of outliers (i.e., Studentized residual >3) were deleted to satisfy the normal theory assumption (Myers 1990:92, 227).
[d] $P < 0.001$ for all F-values.
[e] Equations were corrected for heteroscedasticity via a variance-equalizing transformation (Bowerman and O'Connell 1993:266).

Table 2. Predicted dry seed mass (g) per plant relative to ranges of number of dots obscured and species-specific equations (Table 1), Noxubee National Wildlife Refuge, Mississippi, 1994.

Number of dots obscured	Seed mass (g) per plant[a]				
	Common barnyardgrass	Fall panicum	Panic grass	Beakrush	Green bristlegrass
0–20	0.056807	NP[b]	NP	NP	0.024430
21–40	0.120347	NP	NP	0.040799	0.090190
41–60	0.183887	NP	0.016835	0.110259	0.155950
61–80	0.247427	NP	0.037775	0.179719	0.221710
81–100	0.310967	NP	0.058715	0.249179	0.287470
101–120	0.374507	NP	0.079655	0.318639	0.353230
121–140	0.438047	0.012561	0.100595	0.388099	0.418990
141–160	0.501587	0.033221	0.121535	0.457559	0.484750
161–180	0.565127	0.053881	0.142475	0.527019	0.550510
181–200	0.628667	0.074541	0.163415	0.596479	0.616270
201–220	0.692207	0.095201	0.184355	0.665939	0.682030
221–240	0.755747	0.115861	0.205295	0.735399	0.747790
241–260	0.819287	0.136521	0.226235	0.804859	0.813550
261–280	0.882827	0.157181	0.247175	0.874319	0.879310
281–300	0.946367	0.177841	0.268115	0.943779	0.945070
301–320	1.009907	0.198501	0.289055	1.013239	1.010830
321–340	1.073447	0.219161	0.309995	1.082699	1.076590
341–360	1.136987	0.239821	0.330935	1.152159	0.142350
361–380	1.200527	0.260481	0.351875	1.221619	1.208110
381–400	1.264067	0.281141	0.372815	1.291079	1.273870
401–420	1.327607	0.301801	0.393755	1.360539	1.339630
421–440	1.391147	0.322461	0.414695	1.429999	1.405390
441–460	1.454687	0.343121	0.435635	1.499459	1.471150
461–480	1.518227	0.363781	0.456575	1.568919	1.536910
481–500	1.581767	0.384441	0.477515	1.638379	1.602670

[a] Seed yield was predicted by substituting the midpoint of the range of the number of dots obscured into the appropriate species-specific regression equation (Table 1).
[b] Seed yield was not predicted (NP), because of the number of dots obscured was less than the *Y*-intercept of the model, consequently producing negative estimates.

scured dots, and to the accuracy and consistency in dot counting. Additionally, single variable models are not subject to collinearity, which can inflate variances and decrease precision and predictiveness (Myers 1990:125–129).

MANAGEMENT IMPLICATIONS

Counting dots covered by seed on a grid is an easy and efficient technique to estimate seed yield of moist-soil plants. Measuring multiple floristic variables can be tedious, and use of multiple regression models unnecessarily complex. Although processing time was not estimated, counting dots is likely as rapid or faster than measuring multiple phytomorphological variables. Gray et al. (1999*a*) suggested that researchers develop site-specific equations if very precise and accurate estimates of seed yield are desired. Indeed, replication of this study elsewhere would be much easier than multiple regression studies (e.g., Laubhan and Fredrickson 1992, Gray et al. 1999*a*, Sherfy and Kirkpatrick 1999). Nonetheless, equations developed by these researchers are useful and can be used to estimate seed yield of plant species not addressed in our study. We also encourage researchers to develop dot models for these and other moist-soil plant species in different locations.

Our dot grid can be recreated by typing periods on paper (21.25 × 27.5 cm) at a density of 9 dots/cm^2 (Gray 1995:137). Bolded Courier font (20 pt) with 0.5 line spacing can be used to create the dot density. Grids can be laminated for weather resistance and mounted on a board. Users can determine number of dots covered by seed while in the field by collecting a sample (e.g., n = 20–30) of inflorescences for each plant species, laying each inflorescence on a grid and flattening it with a piece of plexiglass (or similar transparent substance), and counting all dots partially or completely obscured by seed. If a plant has ≥2 inflorescences, then number of obscured dots should be summed across inflorescences. Mean number of dots obscured per species can be inserted into the appropriate species-specific equations, or our precalculations can be used to estimate seed mass (g) per plant (Tables 1, 2). Gray et al. (1999*a*) addressed procedures to estimate seed yield per unit area (e.g., kg/ha) and to calculate waterfowl foraging carrying capacity of moist-soil habitats.

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