Technical Notes:

Moisture Meter Performance I. Corn Over Five Crop Years

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ABSTRACT

THE long-term accuracy of the 1981 Iowa-Illinois moisture-meter calibrations was evaluated by meter-to-oven comparisons on 2999 samples from the 1979-1983 crop years. Although the five-year average accuracy of the trade meters Steinlite SS250, Dickey-john GACII, and Motomco 919 was ± 0.5 percentage point relative to the air-oven up to 25% moisture (wb), there was up to ± 0.7 point accuracy variation among crop years. A year-to-year component was added to the previously published variance model; this component represents about 35% of total variance of a meter test relative to an oven test.

INTRODUCTION

In recent years, corn moisture measurement has generated considerable scientific and governmental interest. An accurate moisture test is important to grain trading; economic value of corn changes 5 to 8 cents/bu per percentage point change in moisture.

Modern moisture meters measure dielectric properties and convert them to percentage moisture. Many corn properties affect its dielectric characteristics, among them temperature, bulk density, physical condition, variety (Nelson, 1984; Hemeda et al., 1982; Nelson, 1981), as well as some large and as yet unidentified factors (Hurburgh et al., 1985). Modern meters correct for temrperature and density; the other factors contribute to measurement variability.

Through the efforts of the Iowa-Illinois Moisture Measurement Task Force, corn calibrations were improved for the 1980 crop year, then updated to their present form for the 1981 crop year (Hill et al., 1981). The 1981 Iowa-Illinois corn calibrations, based on the official United States Department of Agriculture (USDA) air-oven method (USDA, 1976), are now used for trade in Iowa and Illinois and by the Federal Grain Inspection Service (FGIS) of the USDA. Details of these calibrations have been published by Hurburgh et al. (1985) and Paulsen et al. (1983).

The Iowa-Illinois calibrations were adopted after two years' study because the large discrepancies among meter brands demanded immediate action. The degree to which growing season affected accuracy was not known, nor was a year-to-year component included in the variance analysis of Hurburgh et al. (1985).

OBJECTIVES

1. Determine the accuracy of the 1981 Iowa-Illinois corn calibration over five growing seasons.
2. Refine prior estimates of moisture-measurement variance components to include a year-to-year component.

MATERIALS AND METHODS

The three most popular trade-type moisture meters were used, Steinlite SS250, Motomco 919, and Dickey-john GACII. Motomco 919 is the meter used by FGIS for all official inspections. Calibrations were SS250: No. 4 and No. 4 high-moisture modules; Motomco: C-1-B, C-12, and C-13 conversion charts; and GACII K1 - K9 constants dated 9/1/81.

The references method for corn moisture is the 72-h, 103°C whole-grain method approved by FGIS (USDA, 1976). Our oven procedure was cross-checked annually against that of the FGIS Standardization Laboratory. There was never more than a 0.2 percentage-point difference between laboratories.

Combine-shelled corn samples from crop years 1979-1983 were used in this study. The samples were distributed as follows: 291 in 1979, 568 in 1980, 772 in 1981, 984 in 1982, and 384 in 1983 for a total of 2999. The unequal numbers per year arose because sample distribution was controlled by other research projects, not the meter calibration study. Laboratory procedure was maintained as given in Hurburgh et al. (1985).

The data, between 10% - 32% wet basis moisture content by the oven method, were divided into 11 increments of 2% oven moisture for calculation of bias and application of the variance model developed by Hurbrugh et al. (1985). Bias, defined as meter-minus-oven differences, was measured by the arithmetic (not weighted by number of samples) averages of the individual-year errors by increment and model. In any increment, only years containing three or more samples were included.

the variance model was:

$$V_{wy} = V_{ss} + \frac{V_m}{n_m} + \frac{V_o}{n_o} \qquad \ldots\ldots\ldots\ldots\ldots\ldots [1]$$

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where:

V_{wy} = variance between meter and oven within a crop year
V_{ss} = variance of samples within a year
V_m = variance of meter replicates on a sample
V_o = variance of oven replicates on a sample
n_m = number of meter replicates per sample (=3)
n_o = number of oven replicates per sample (=3)

A year-to-year component was added:

$$V_{mo} = V_y + V_{ss} + \frac{V_m}{n_m} + \frac{V_o}{n_o} \quad \ldots\ldots\ldots\ldots\ldots\ldots [2]$$

where:

V_{mo} = total variance between meter and oven
V_y = variance among years.

The V_m and V_o data were the individual sample variances among replicates of all brands and years combined. the 15 V_{ss} (3 meters x 5 years) data points for each moisture increment were obtained by rearrangement of equation [1] within each year and meter model. The variances of meter errors (meter-minus-oven) yielded three values of V_{mo} per increment. V_{mo}, V_{ss}, V_m, and V_o were then regressed against oven moisture. V_y was calculated by rearrangement of equation [2], with the respective regression equations substituted for V_{mo}, V_{ss}, V_m, and V_o. Because the V_{mo} regression equation was specific to $n_m = 3$ and $n_o = 3$, a general expression for V_{mo} was found by substitution of individual component equations into equation [2]. As with bias, variance component data points were not weighted by number of samples within an increment and year.

RESULTS AND DISCUSSION

The 5-year average biases are plotted on Fig. 1. Up to 25% moisture, the meters were within 0.5 points of the oven and each other. The lone exception, Motomco in the 20 to 22 % increment, was caused by a discontinuity between the low-relative to the oven did change substantially from year to year, the meters always maintained the same position relative to each other. Thus, factors affecting meter accuracy affected all brands similarly.

Regression equations for the variance components as functions of oven moisture, M_o, were:

$$V_{mo} = 0.016486\, M_o^2 - 0.57931\, M_o + 5.339 \quad \ldots\ldots [3]$$

$$R^2 = 0.89$$

$$V_y = 0.003709\, M_o^2 - 0.13542\, M_o + 1.371 \quad \ldots\ldots [4]$$

by subtraction in equation [2]

$$V_{ss} = 0.012276\, M_o^2 - 0.43326\, M_o + 3.881 \quad \ldots\ldots [5]$$

$$R^2 = 0.53$$

$$V_m = 0.000301\, M_o^2 - 0.00777\, M_o + 0.065 \quad \ldots\ldots [6]$$

$$R^2 = 0.54$$

$$V_o = 0.000599\, M_o^2 - 0.02409\, M_o + 0.254 \quad \ldots\ldots [7]$$

$$R^2 = 0.30$$

All equations had minima between 15% and 19% moisture. In Hurburgh et al. (1985), V_o was a constant 0.0296; the addition of 1981-1983 data showed V_o also to be a function of moisture content. The years component was substantial, contributing a standard deviation ($V_y^{1/2}$) of 0.4 — 0.6 percentage points in the normal trading range 14% to 25% moisture.

Table 1 gives the relative contribution of the four variance components, and the predicted standard deviation ($V_{mo}^{1/2}$) of a single moisture-meter test relative to the oven. The dominance of years (V_y) and samples within years (V_{ss}) was clear, as together they comprised 90 to 95% of variance. The relative share of variance attributable to year became less at both ends of the moisture range.

Both V_y and V_{ss} reflect variations in grain dielectric properties relative to moisture content. From meter-design standpoint, the greatest need is an understanding of causative factors for these variations. More precise

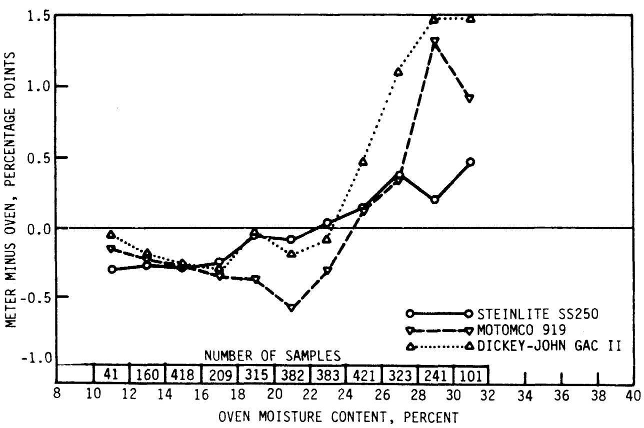

Fig. 1—Meter-to-oven comparison for 1979-1983 corn.

TABLE 1. RELATIVE MAGNITUDE OF CORN MOISTURE VARIANCE COMPONENTS ACROSS FIVE CROP-YEARS*

Variance source	Percentage of total variance at oven moisture content 10%	15%	20%	25%	30%
Years, V_y	32.2	50.6	47.1	27.8	23.9
Samples within years, V_{ss}	64.4	41.9	41.1	66.0	71.4
Meter precision, V_m	1.4	4.7	9.8	5.4	3.8
Oven precision, V_o	2.0	2.8	1.4	0.8	0.9
Total, V_{mo}	100.0	100.0	100.0	100.0	100.0
	Standard deviation relative to the oven, $V_{mo}^{1/2}$, percentage points				
	1.10	0.59	0.55	1.05	1.64

*Variances calculated from regression equations, assuming one meter-test per sample.

electronic components or reference methods will not improve moisture measurements appreciably.

CONCLUSIONS

Based on corn moisture data from the 1979-1983 crop years:

1. Up to 25% oven moisture, the Iowa-Illinois corn moisture calibration gave 5-year average errors with respect to the oven of ± 0.5 percentage points.
2. Consistency of the meters relative to each other does not change across growing seasons.
3. The magnitude of the variance components are best modeled as quadratic functions of moisture content, all with minima between 15% and 19% moisture.
4. Year-to-year differences in corn properties account for 24 to 50% of meter-to-oven variance, sample-to-sample differences with a year account for 40 to 70%, and instrument precision 1 to 10%. The relative importance of the variance components changes substantially with moisture content.
5. Average meter accuracy relative to oven has a standard deviation of 0.4 to 0.6 percentage points among growing seasons.

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