Use of Empirical Equations to Describe the Effects of Plant Density on the Yield of Corn and the Application of Such Equations to Variety Evaluation

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ALTHOUGH it has been known since 1891 (Morrow, 4) that field corn varieties differ in plant densities producing maximum grain yields, varietal yield comparisons most often are made in trials where all varieties are grown at a single, common plant density. In cases where such procedures are used to compare varieties that produce maximum yields at widely different plant densities, distorted pictures of relative yield capacities are apt to result. In order to avoid distortion in cases of this kind, a description is needed for each variety of the effect of plant density on yield over a range of plant densities including that producing the varietal yield maximum. In order to limit the cost of varietal plant density descriptions, the method used should limit the number of experimental plant densities and computational complexity required.

In 1944 Pickett (5) described the effect of plant density on the yield per acre of a sweet corn variety with a quadratic equation that had a non-zero term for yield at zero plant population. Pickett used the maximum estimated from this equation in developing a recommendation for a plant density to be used for growing the variety tested. Later, Duncan (3) proposed that under Corn Belt conditions the log of the grain yield per plant was a linear function of plant density. Since yield per acre is the product of yield per plant and plant density, he multiplied the yield per plant equation by plant density to obtain an equation for yield per acre. Duncan pointed out that use of such equations permitted estimation of the maximum yield of a variety and the plant density producing that yield from trials with as few as two plant densities per variety. The author (9) used a similar pattern of equations to describe the effects of plant density on yield of fresh market sweet corn. These equations differ from Duncan's in that the basic equation used is a linear relation between plant density and yield per plant, rather than log yield per plant. Consequently a parabolic function was obtained for yield per acre instead of an exponential function. These parabolic yield equations also can be obtained from as few as two plant populations per variety and are simpler to compute than exponential equations.

In this paper additional evidence is presented indicating that such parabolic equations adequately describe yield responses of fresh market sweet corn within the limits of plant density and environment that have been examined. Evidence is also presented to suggest that equations of the same form may apply to field corn and processing sweet corn. These equations differ from Duncan's in that the basic equation used is a linear relation between plant density and yield per plant, rather than log yield per plant. Consequently a parabolic function was obtained for yield per acre instead of an exponential function. These parabolic yield equations also can be obtained from as few as two plant populations per variety and are simpler to compute than exponential equations.

**MATERIALS AND METHODS**

Empirical estimates—1. Yield per plant, \( y = a + bP \), \( P \) is plant density in thousands of plants per acre while \( a \) is the intercept and \( b \) is the slope obtained using the usual methods of linear regression (6, 7).

2. Yield per acre, \( Y = a + bP \).

3. The population producing the maximum yield per acre, \( P_M = -\frac{a}{2b} \).

4. The maximum yield per acre, \( Y_M = a^2/4b \).

5. The average yield for a range of plant populations, \( Y_a = \left[ \frac{a^2}{4b} \left( P_a - P_b \right) + \frac{a}{b} \left( P_a^2 - P_b^2 \right) \right] / \left( P_a - P_b \right) \) where \( P_a \) is the upper limit of the population range and \( P_b \) is the lower limit. \( Y_a \) is obtained by integrating equation 2 between \( P_a \) and \( P_b \) and dividing by the range. Since equation 2 is symmetrical about its maximum, \( P_a \) can be substituted for \( P_b \) when the range is centered on \( P_a \).

Usually the values of \( a \) and \( b \) have been obtained from regressions based on means averaged over all replicates of a variety in a trial. When analyses of variance have been computed for \( Y_a \) and \( Y_M \) regressions have been obtained for each variety within each replicate of a trial.

Experimental technique—This series of trials consisted of a total of 6 plantings made up of experiments put in at 2 planting dates at each of 3 locations. Planting dates were approximately May 1 and June 1, 1960. Locations were at Gowanda, Ithaca, and Hurley, N. Y. Gowanda is in western New York, Ithaca is about 150 miles east of Gowanda, and Hurley is in the Hudson Valley (Ulster County) about 150 miles east of Ithaca. Monthly means for temperature and rainfall are about the same for Ithaca and Gowanda, while temperatures and rainfall means are somewhat higher for Hurley. In 1960, temperatures followed this pattern, but rainfall did not. During July, Gowanda did not receive rain for a 3-week period just prior to tasseling of the May planting and the mid-whorl stage of the second planting. At Ithaca firing of the lower leaves of the May planting shortly before harvest probably resulted from inadequate moisture supply. Moisture supply was ample for both plantings at Hurley.

Fertilizer was supplied at probably nonlimiting levels. Rates applied at planting were modified according to soil test values and previous fertilization. Nutrient deficiency symptoms were noted only in the June planting at Ithaca. Soils and fertilizer rates (pounds N-P-K/A.) were as follows:


Each planting consisted of 4 replications of 3 varieties and 8 plant populations in a split plot design with varieties as main plots. The varieties all were F1 hybrids, Golden Security (Asgrow Seed Co.), Hick Surecrop (Jos. Harris Seed Co.), and Gold Cup (Jos. Harris Co.). Both are main season varieties that usually reach a height of 9 feet in New York. Gold Cup (Jos. Harris Co.) is 2 to 3 days earlier than the other...