A Crowding Model for Soybean

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The yield of a crop in any given environment is dependent on the availability of resources and genetic potential. Growing plants in crop communities introduces competition for light, nutrients, moisture and CO_2. Plant density is a major factor influencing competition within a canopy. As density increases, intensity of interplant competition increases and yield decreases. However, yield - density relationships for crops depend not only on the actual plant density but also on spacial arrangement of plants. Yield is favored by a uniform or square planting pattern rather than a rectangular arrangement where the row width is much greater than the distance between plants within the row. Duncan (1984) proposed a mathematical model relating yield to plant density and spatial arrangement in corn.

Crowding between two plants (C_i) is defined as: $\mathbf{C_i = (SF)^{\alpha}}$ (Fig.1)

where SF = Separation Factor = [(Dmax - Separation)/Dmax]

Dmax = Minimum distance between two plants at which competition becomes negligible,

Separation = Distance between two plants, and

α = The curvilinear pattern in which crowding increases with decrease in separation.

Crowding for the crop community is defined as: $\mathbf{C = \sum_{P_i}^{P_1} C_i}$

where P_1 to P_i includes all plants within the circle with a radius of Dmax.

The crowding-yield relationship is defined as: $\mathbf{Ln(Y) = Ln\ (Y_0) + EC}$

where Y = yield/plant in crop

Y_0= yield of a plant grown in isolation

C = total crop crowding

E = effect of crowding on yield

Values of E and Y_0 are constants for any given environment and genotype and are found experimentally.

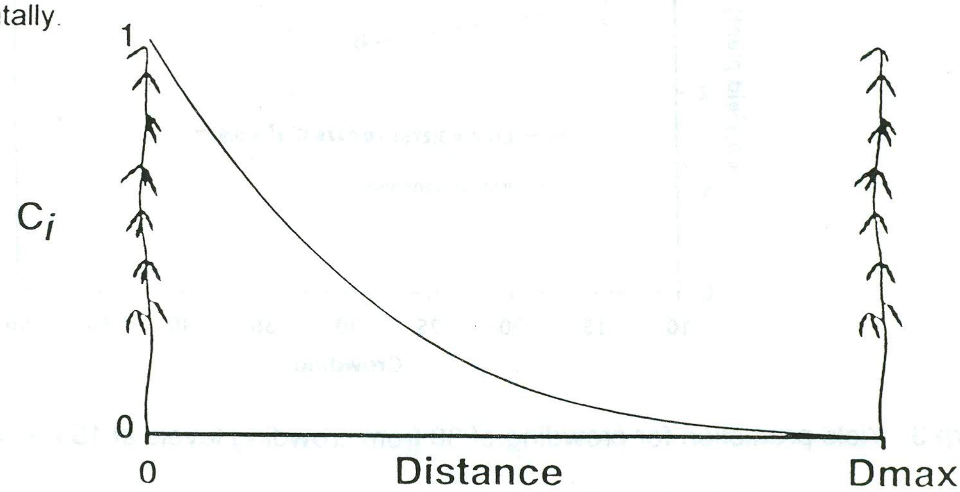

Figure 1. Crowding (C_i) relationship between two plants as defined by Duncan (1984).

In this study four soybean cultivars (V_1 = NK 0066, V_2 = NK 1990, V_3 = PIONEER 9071 and V_4 = PIONEER 9111) were grown at the Univ. of Massachusetts Agronomy Research Farm in 1995 in three densities (25, 50, and 75 plants/m^2) in 25 cm rows. Isolated plants of each were used to quantify the increase in intensity of competition with increased crowding.

Yield per plant decreased 80, 87, and 90 percent compared to isolated plants as density increased from 25 - 75 plants/m^2 respectively. When each cultivar was fitted to the model, variation accounted for ranged from 88% to 97% (Fig. 2). This supports Duncan's theory that a linear relationship exists between the logarithm of yield per plant and crowding. An examination of the model's predicting power using just two densities (Fig. 3) indicated the third density could be predicted with a high level of accuracy. More evaluation however, is needed to examine the model's predictive ability for other changes in spatial arrangement.

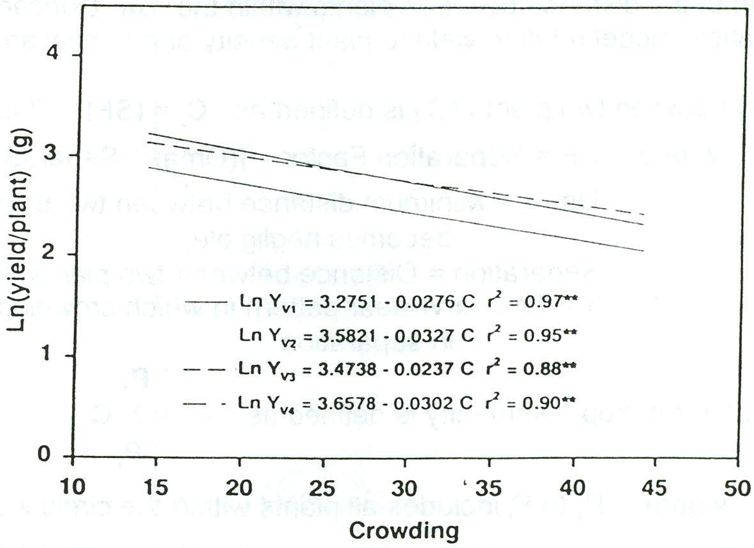

Figure 2. Crowding response of four soybean cultivars.

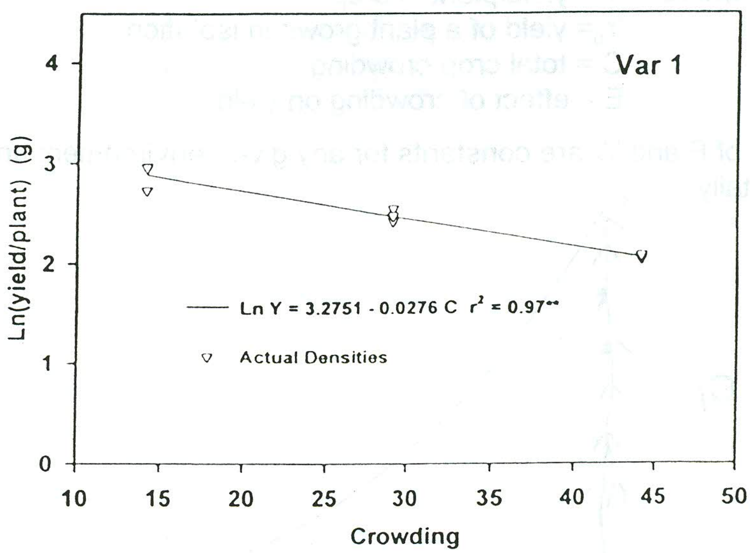

Figure 3. Yield prediction for crowding of 30 from crowding levels at 15 and 45.

Reference: Duncan, W.G. 1984. A theory to explain the relationship between corn population and grain yield. Crop Science 24:1141-1145.