Manipulation of Crowding Stress and Kernel Growth Rate in Corn

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Competition for resources such as light, water and nutrients have long been viewed as an important consideration in the growth and yield of plants. Plant density has been recognized as a major factor determining the degree of competition between plants. Yield per plant decreases as the density per unit area increases. The rate of yield decrease in response to decreasing light available to each plant is also affected by such factors as fertility, level of water availability and genotype. Reduction in yield may be the result of lower number of ears (barrenness), fewer kernels per ear, lower kernel weight or a combination of these components. In dense populations, many kernels may not develop. This occurs in some genotypes due to poor pollination resulting from prolonged silking compared to tassel emergence and/or due to a limitation in assimilate supply that causes kernel and ear abortion. Finding optimum densities that produce the maximum yield per unit area under different environmental conditions and/or genotypes has been a major concern in many investigations.

Kernel yield of corn is determined in part by kernel weight, which is a function of grain filling rate (mg day^{-1}) and grain filling duration (days). Genetic differences among corn hybrids exist for kernel weight and for both rate and duration of kernel filling. Kernel growth may also be influenced by environmental conditions.

The timing of competitive stress may also be important. Many studies indicate that competition after flowering has more detrimental effects on grain yield compared to competitive pressure during vegetative growth. Isotope labeling studies also have shown that less than 10% of grain yield is attributable to assimilates formed before silking. However, assimilated carbohydrate before silking may establish sink capacity and thus may be quite important in determining the final yield. Various environmental stresses may also increase the contribution of pre-silking assimilates to yield.

The objectives of this research were to:

1. Determine the effect of a wide range of plant density on kernel weight and kernel growth rate.
2. Examine the effect of a reduction in competition pressure, at different growth stages of corn, on kernel development.

A two year field study, part of a larger five year study, was conducted at the UMass Agronomy Research Farm in South Deerfield. In this experiment two corn hybrids, a single ear hybrid and a semi-prolific hybrid were studied in each year. Five plant densities; 3, 4.5, 6, 9, and 12 plants m^{-2} combined with 4 removal treatments; no removal (R_0), and removal of alternate plants in rows at vegetative growth {38 days after emergence (DAE)=R_1}, 50% tassel emergence (59 DAE for the semi-prolific hybrid and 73 DAE for the single ear hybrid (R_2)), and early grain filling stage (80 DAE for the semi-prolific hybrid and 88 DAE for the single ear hybrid (R_3)) were investigated.

One larger sub-plot for each hybrid in each replication was allocated to widely spaced or "isolated plants", which were separated by 2 m between plants (0.25 plants m^{-2}). Ear samples were taken 4-7 times, depended on hybrids during rapid (linear) stage of kernel filling. A complete ring of kernels from each ear at the base (8th kernel from the bottom), middle (19th kernel from the bottom), and tip (29th kernel from the bottom) was taken and kept separate. The number and dry weight of kernels at each position was then determined. Kernel growth rate was determined by linear regression of weight per kernel verses sampling date.

Density Effect:
Total kernel yield per plant decreased 75% and 80% compared to isolated plants in the single ear hybrid and the semi-prolific hybrid respectively, as density increased (Figures 1 and 2). The reduction in total kernel yield was mostly due to the reduction in number of productive ears per plant in the semi-prolific hybrid and number of kernels per row in the single ear hybrid. Both hybrids showed a decrease in weight per kernel as density increased. The decline in weight per kernel with density was greater in the single ear hybrid than in the semi-prolific hybrid. The reductions were 21% and 11% when weight per kernel in the highest density was compared to that in the lowest density. The overall means of kernel growth rate in the semi-prolific hybrid and the single ear hybrid were 6.6 and 7.0 mg/kernel/day, respectively.

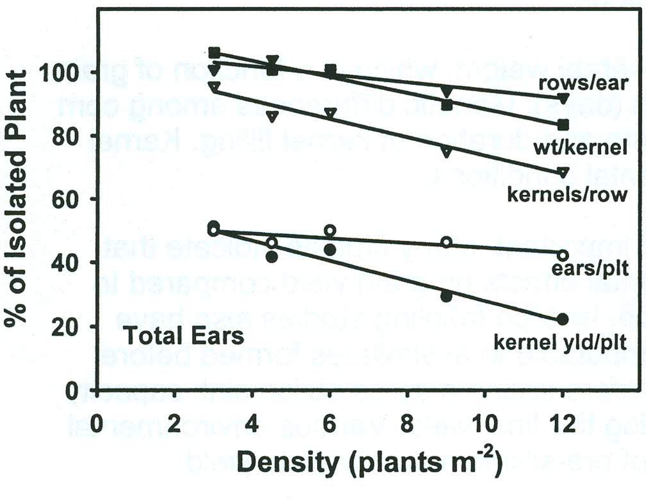

Figure 1. The response of total kernel yield per plant and yield components for the single ear hybrid as a percentage of isolated plant.

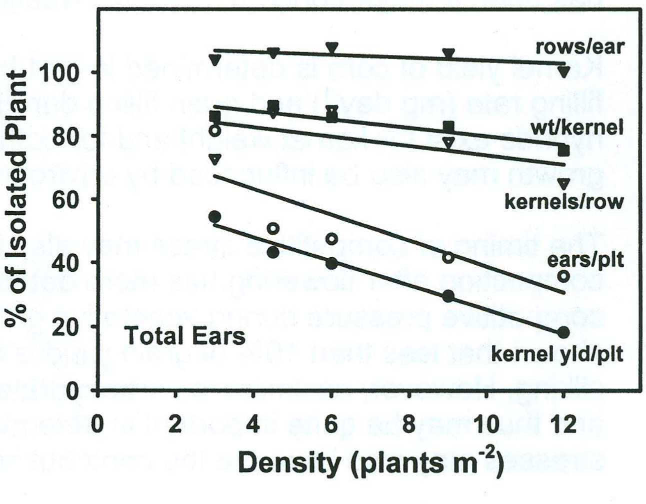

Figure 2. The response of total kernel yield per plant and yield components for the semi-prolific hybrid as a percentage of isolated plant.

Tables 1 and 2 show the effect of plant density on kernel growth rate at different positions of corn ear. As crowding stress intensified, the kernel growth rate reduced gradually. The rate of kernel filling in both hybrids was about 25% slower in highest density compared to the lowest density. The average kernel growth rate of isolated plants was lower than the lowest density in both hybrids. This indicates that some within-plant competition occurred when tiller and secondary ears were produced. Kernel Growth Rate also varied in different positions within the ear. Kernels at the middle of the ears had similar growth rate as those located at the base, but tip kernels showed a 19% and 15% reduction in the semi-prolific hybrid and the single ear hybrid respectively, compared to the basal kernels.

Table 1. The effect of plant density on kernel growth rate of the single ear hybrid at different positions of the corn ear (average of 2 years).

	Position		
Density (plts. m^{-2})	Bottom	Middle	Top
Isolated	8.41	8.02	7.21
3.0	8.47	7.98	7.80
4.5	7.81	7.56	7.08
6.0	7.27	6.48	5.97
9.0	6.16	6.26	5.41
12.0	6.45	6.14	5.60

Table 2. The effect of plant density on kernel growth rate of the semi-prolific hybrid at different positions of the corn ear (average of 2 years).

	Position		
Density (plts. m^{-2})	Bottom	Middle	Top
Isolated	7.17	6.87	6.41
3.0	7.88	7.58	6.66
4.5	6.95	6.56	5.84
6.0	7.39	6.90	5.54
9.0	7.23	6.86	5.95
12.0	6.39	6.11	4.42

Removal Effect:

When compared to their initial densities, the amount of yield compensation with removal of alternate plants was greatest the earlier the removal occurred. The average decrease in grain yield compared to plants grown at the initial non-thinned density (R_0) was 0, 22 and 28 percent in the single ear hybrid and 2, 15 and 28 percent in the semi-prolific hybrid for R_1, R_2 and R_3, respectively. The results indicated that early competition between corn plants during the vegetative stages of growth had almost no effect on final grain yield. Crowding stress between vegetative stage and anthesis had the greatest impact, with 22% and 13% yield reduction (averaged over densities and year) for the single ear hybrid and the semi-prolific hybrid, respectively. The higher the density, the lower increase in grain yield from releasing competition pressure by plant removal.

The effect of plant removal on kernel growth rate was not significant. The results indicated that the reductions in grain yield caused by crowding stress in vegetative stage of growth and anthesis were due to the other yield components rather than kernel growth rate.