Radiation interception accounts for the effects of plant population on maize yield

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Introduction

The effect of plant population on maize yield has been studied for many years (Duncan, 1958; Ordas and Stucker, 1977; Aldrich *et al.*, 1986), and one may justifiably ask, 'why more?'. There are two main answers. First, the plant population at which maximum maize yield is attained has increased steadily since the 1930s, from c. 30,000 (Cardwell, 1982) to its present level of c. 100,000 plants/ha (Begna *et al.*, 1997), and so regular revisits are appropriate. Second, many plant population studies report mainly on responses of yield and yield components, without attempting to explain the mechanisms underlying the responses. To construct robust models of maize growth and yield that are valid over a wide range of plant population densities, we must understand the mechanisms by which yield varies with population.

Here we describe the effects of plant population on maize growth and yield, primarily by relating them to changes in the crop's interception of radiation. We focus on the response of the crop canopy to plant population, and examine the appearance, size and senescence of individual leaves.

Materials and Methods

Three hybrids of varying maturity (Pioneer hybrids 3905, 3730 and 3476) were grown at 10 populations ranging from c. 30,000 to 160,000 plants/ha. Plots were hand-sown on 30 October, 1997, and were subsequently fertilised and irrigated to maximise yield. Daily profiles of leaf area index (LAI) and radiation interception (RI) were constructed from regular observations of times of leaf appearance, full expansion and senescence, and fully expanded leaf size. Leaf senescence is presented as fraction of senesced leaf area (FSA), where FSA is senesced leaf area index divided by LAI. Mature crop biomass and yield were measured on 20 randomly selected plants from each plot.

Results and Discussion

Maize biomass and grain yield increased with the $\log_{10}$ of plant population and the response to population did not differ among hybrids. Consequently, all data are expressed as the average for three hybrids.

Maize yield increased with plant population because the amount of radiation intercepted by the crop canopy increased with population (Fig. 1). The mechanism by which this occurred was described simply in terms of the effects of population on leaf size, leaf duration and harvest index, as there were no important effects of population on phenology.

The mechanisms by which plant population affected maize yield can, therefore, be described in six main steps:

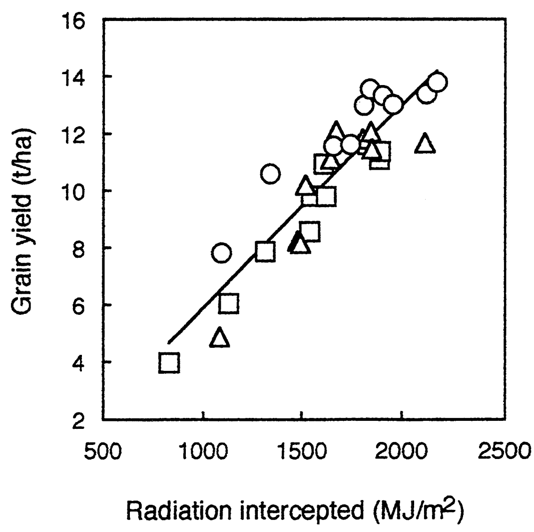

Figure 1. Relationship between grain yield and radiation intercepted by maize hybrids: O P3476; ▲ P3730; □ P3905.

1. the size of leaves in the upper canopy declined with increased population, and this reduced the maximum total leaf area per plant (by 17 cm^2 per 1000 plants/ha; R^2=0.89);
2. maximum TLAI, however, increased with population (by 0.03 per 1000 plants/ha; R^2=0.79) because the reduced leaf area per plant was more than compensated for by the increase in the number of plants per unit area;
3. opposing this trend was the increase in FSA with population (2.75 x 10^{-4} per 1000 plants/ha; R^2=0.97), caused by the reduced duration of lower canopy leaves as population increased;
4. the net result was that the amount of radiation intercepted by green leaves increased with the log_{10} of population (1280 MJ/m^2 per log_{10} plants/ha; R^2=0.81) because the increase in TLAI more than compensated for the increased erosion of LAI caused by enhanced senescence at increased populations;
5. there was no effect of population on radiation use efficiency, so the increase in RI with population translated directly into increased biomass (1.2 g/MJ solar radiation; R^2=0.86);
6. yield increased with population both because a) biomass increased with population, and b) harvest index increased with increasing biomass, as shown by the relationship between grain yield and biomass: yield = 0.61 x biomass - 1.4 (R^2=0.96).

It is therefore possible to describe simply the effects of plant population on biomass and yield of maize by accounting for its impact on the crop canopy. Despite the negative impact of plant population on the size and duration of individual leaves, the increased number of leaves per unit area permitted greater interception of radiation during the season, and this translated directly into increased biomass and grain yield. Consequently, maximum grain yield was achieved at a plant population of c. 120,000 plants/ha.

Conclusions

The effects of plant population on radiation interception and consequently biomass and yield of maize were described simply in terms of basic canopy variables. These effects and their implications for models designed to predict maize yield will be discussed further in another publication.

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References

Aldrich, S.R., Scott, W.O. and Hoeft, R.G. 1986. Planting for high yields. *In* Modern Corn Production (eds., S.R. Aldrich, W.O. Scott and R.G. Hoeft. Illinois), pp. 75-89. A and L Publications.

Begna, S.H., Hamilton, R.I., Dwyer, L.M., Stewart, D.W. and Smith, D.L. 1997. Effects of population density on the yield and yield components of leafy reduced-stature maize in short-season areas. *Journal of Agronomy & Crop Science-Zeitschrift fur Acker und Pflanzenbau* ***178***, 103-110.

Cardwell, V.B. 1982. Fifty years of Minnesota maize production: Sources of yield increase. *Agronomy Journal* ***74***, 984-990.

Duncan, W.G. 1958. The relationship between corn population and yield. *Agronomy Journal* ***50***, 82-84.

Ordas, A. and Stucker, R.E. 1977. Effect of planting density on correlations among yield and its components in two corn populations. *Crop Science* ***17***, 926-929.