Ear Barrenness of Corn as Affected by Plant Population

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Utilizing hybrids, heavy fertilizer applications and doubled plant populations, the grain yield per ha has doubled in the past twenty years in Japan. However, increasing stalk and ear barrenness associated with increasing plant populations pose a serious problem for further yield increases utilizing higher plant populations.

The purpose of this paper is to present recent results of the research at the Tohoku National Agricultural Experiment Station on the problems concerning the cause and mechanisms of ear barrenness at high plant populations[6].

Incidence of barren and earless plants at different populations

Barren ear and earless plants augmented with increased plant populations as shown in Table 1. The percentages of normal ear plants, on which all initiated kernels were fully developed, were 97, 85, 62, 38, and 13 at the populations of 4,000, 25,000, 50,000, 75,000 and 100,000 plants per ha, respectively. The remainders at each population were barren ear and earless plants.

Table 1. Percentages of normal ear, barren ear and earless plants at five different plant populations

Population, 1,000 plants/ha	Normal ear	Barren ear	Earless
4	97	3	0
25	85	15	0
50	62	38	0
75	38	62	0
100	13	82	5

The defective types of the barren ears at the higher two populations were quite different from those at the lower three populations as shown in Plate 1. The almost barren ears at the higher two populations had incompletely developed kernels on both tips and one-sided rows of the ears, which showed unfilled tip ends and dropped rows or one-sided shrivelling of kernels on the ears, and while the barren ears at the lower three populations failed in developing kernels only the uppermost tip ends.

These incompletely developed kernels on the barren ears were examined whether they formed black layers in their placental regions or not. Daynard and Duncan[3] reported that no black layer development was seen in nonfertilized florets and that the presence or absence of a black layer in a floret at maturity serves as a good indicator of whether fertilization has occurred.

In this experiment the undeveloped kernels, more than 90 per cent at any populations, showed complete black layer development.

Therefore, it was assumed that the greater number of these undeveloped kernels initiated on the barren ears were fertilized but that their development ceased during the grain filling period.

Leaf characteristics as affected by plant population

The potential amount of grain that can be produced after fertilization depends upon

Left to right: Normal ear from 4,000 plants/ha plot, barren ear with unfilled tip end from 50,000 plants/ha plot, barren ear with one-sided shrivelling kernels from 100,000 plants/ha plot

Plate 1. Normal and barren ears at different plant populations

the photosynthetic capacity of plant population during the grain filling period. Tanaka and Yamaguchi[9] reported that more than 90 per cent of the weight of grain is derived from the photosynthesis product during grain filling. Therefore, canopy structure in relation to leaf characteristics of individual plant after silking is probably important to develop grain completely.

Since increasing plant populations makes LAI larger, more mutual shading at high populations results in greater light interception. Fig. 1 shows the relationships between LAI and light interception or barren ear plus earless plants. Here, the interception values were calculated by subtracting the light penetrating to the bottom of canopy from the total incident light at silking. The number of barren ear and earless plants, which was closely associated with LAI, increased with increased light interception.

An experiment conducted to determine optimum LAI by Iwata and Okubo[5] showed

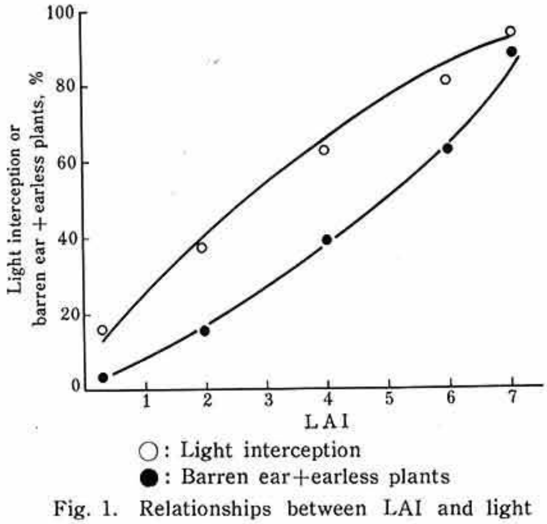


Fig. 1. Relationships between LAI and light interception or barren ear plus earless plants

that a LAI of 4~6 at the time of silking on fertile soil was sufficient to maximize grain yield. Allison[1] reported that when LAI increases above 6 the amount of dry matter produced per plant after flowering is not great because of more light interception. Under such conditions, photosynthates available to develop all kernels initiated are presumably insufficient.

Moreover, barren ear and earless plants caused by insufficient photosynthates increase respiratory rate and decrease photosynthetic rate because of much more carbohydrate accumulation in leaves and stalks as reported by Moss[7], and Tanaka and Yamaguchi[9].

Increasing plant populations made leaf area per plant smaller and leaves thinner as shown in Table 2. The smaller leaf area and thinner leaves have low efficiency for capturing the energy of the sun and probably result in less photosynthates. The thinner leaves have also their reduced leaf angles increasing mutual shading. The importance of erect leaves associated with less light interception has been already studied.

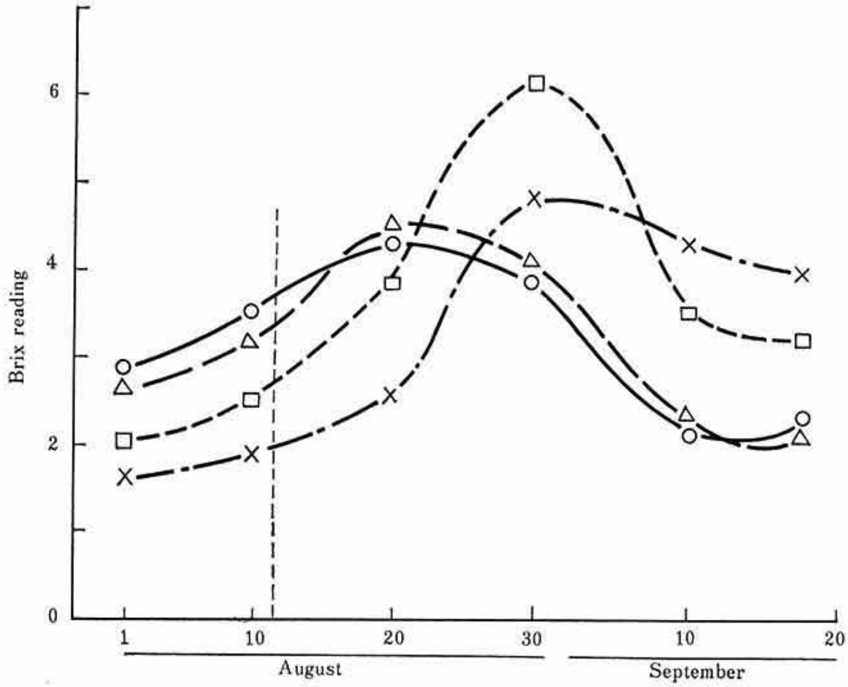
Pendleton et al.[8] described that a higher grain yield was obtained from maintaining leaves in an upright orientation than from normal leaf orientation. Thus improving plant type might allow plant populations to augment far beyond the present day standards without increasing barrenness.

Table 2. LA1, leaf area per plant and leaf area to leaf weight ratio (LA/LW) at silking time at different populations

Population, 1,000 plants/ha	LA1	Leaf area, cm^2/plant	LA/LW, cm^2/g
4	0.30	8068	148
25	2.06	8436	153
50	4.03	8063	164
75	6.00	7996	200
100	7.10	7095	197

Sugar concentration in stalks as affected by plant populations

Although corn stalk is not an effective



○: 25,000, △: 50,000, □: 75,000, ×: 100,000 plants/ha
Vertical dashed line indicates the date of silking
Fig. 2. Changes with time in the values of Brix reading in stalks

storage organ for sugar, this mobile sugar in stalk is important to maintain relatively uniform kernel growth in spite of diurnal and day-to-day variation in photosynthesis as Duncan et al.[4] stated.

Relative values of sugar concentration in the stalks were indicated by the hand sugar refractometer readings[2),10)]. As shown in Fig. 2, the Brix readings were relatively higher at the lower plant populations prior to the rapid grain filling stage, while after this stage they were relatively higher at the higher populations.

It might be assumed that the low values before this stage at the higher populations, as indicated by the smaller amounts of photosynthates per plant, were due to over mutual shading and smaller leaf area per plant, and that the higher values after this stage, as indicated by higher sugar accumulations in the stalks, were ascribed to the limited size of sink for photosynthates. They were dependent on the balance of the amount of photosynthates and size of the sink for photosynthates in the plants.

Thus, during the grain filling period of a corn plant there is a source-sink relationship in which the leaves and the ears can be considered as the source and the sink, respectively, as already mentioned by Tanaka and Yamaguchi[9)].

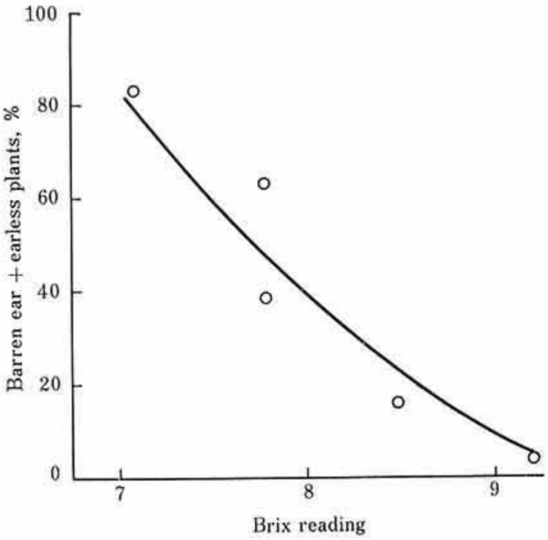


Fig. 3. Relationship between Brix reading in two internodes from just above and below the uppermost earnode at silking time and barren ear plus earless plant incidence

Fig. 3 shows that there was a linear relationship between the number of barren ear plus earless plants and Brix readings in the internodes from above and below the uppermost earnode at the silking time. The negative proportionality between them can be used as a basis for predicting the incidence of barren ear and earless plants.

Cause and mechanisms of stalk and ear barrenness

Based on the results mentioned above it is concluded that the insufficient photosynthates during the grain filling period caused by over mutual shading, smaller leaf area per plant, thinner leaves and large light interception at high plant populations are probably a major determinant of barren ear and earless plants. The diagrammatic representation of the cause and mechanisms of barren ear incidence at high plant populations is simply illustrated in Fig. 4.

There was a critical stage for incidence of barren ear and earless plants in an artificial shading period experiment. Shading of each 20 days for 40 days in between the silking time was more detrimental to ear and grain development than shading for the other periods.

Shading for the period prior to silking resulted in earless plants and shading for the period after silking resulted in barren ears, which depended upon the stages of ear and grain development.

At high plant populations the incidence of barren ear and earless plants may play a role in a defense mechanism for survival, by aborting some of the initiated ears or kernels while allowing others to develop fully when the available photosynthate was not enough to develop all the ears and kernels initiated as Daynard[3)] stated.

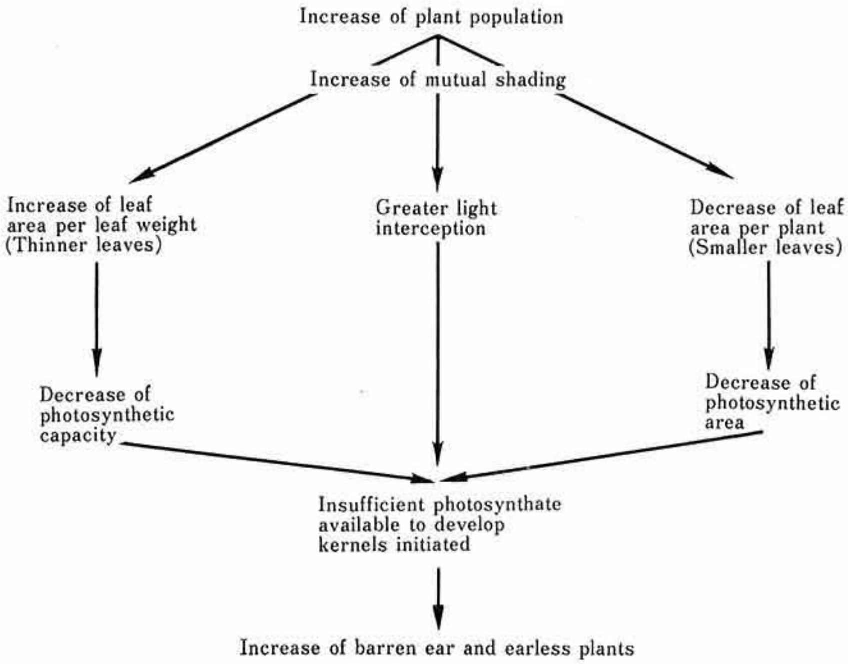


Fig. 4. A simplified scheme of mechanisms of barren ear incidence caused by high plant populations

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