15. A NEW TECHNIQUE FOR HIGH YIELD MAIZE CULTURE IN JAPAN

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Introduction

In Japan, upland fields are located mainly on volcanic ash soils which are low in productivity. On these poor soils maize has been grown at low plant populations for a long time. Recently, as a result of heavy fertilizer applications and soil improvement, maize is being grown at higher plant populations.

The maize plant is inherently less capable of adjustment to poor stands than other members of the grass family. Therefore, it is important to adjust the plant population to the productivity level of the soil. Hume stated 60 years ago that "Plant corn thicker if the land is high in productivity and thinner if the land is low in productivity."

Maize is a "rich-land" crop. Therefore, it is essential to improve the soils for maize. Because the volcanic ash soils in Japan are extremely deficient in available phosphorus the improvement of these soils reqpires heavy applications of phosphorus fertilizer in order to increase the available phosphorus.

The purpose of this lecture is to present recent results of the research at the Tohoku National Agricultural Experiment Station on the problems concerning the most suitable plant populations to use and the improvement of volcanic ash soils for high yields of maize grain.

Maize Plant Populations in Relation to Soil Productivity

A plant population study was conducted at the Tohoku Agricultural Experiment Station using a maize hybrid named Tomorokoshi Ko No. 7. The corn was planted and grown at four different rates: 250, 500, 750 and 1,000 plants per *are* on fields of three different soil productivity levels. A subsoil field was used for the low productivity level, an eight-year field after reclamation for the medium productivity level, and an eight-year field with an application of 400 kg of farm manure per *are* after reclamation for the high productivity level.

1. High grain yields from high plant populations on the high productive soil:

The data are presented graphically in Fig. 1. One fact is discernible at a glance: increasing the soil productivity level increases the number of plants required for maximum yields. The highest yield on the low productive soil was 61.6 kg per *are* at the population of 500 plants per *are*, on the medium productive soil it was 80.1 kg per *are* at 750 plants per *are*, and on the high productive soil 86.6 kg per *are* at 750 plants per *are*. Although on both the medium and high productive soils the highest yields were obtained at the same population, it was postulated that the maximum yield would be obtained at a higher population on the high than on the medium productive soil. This may indicate that some factor not studied in this experiment, such as hybrid type etc., has become limiting at the highest populations. However, in general, the data indicate

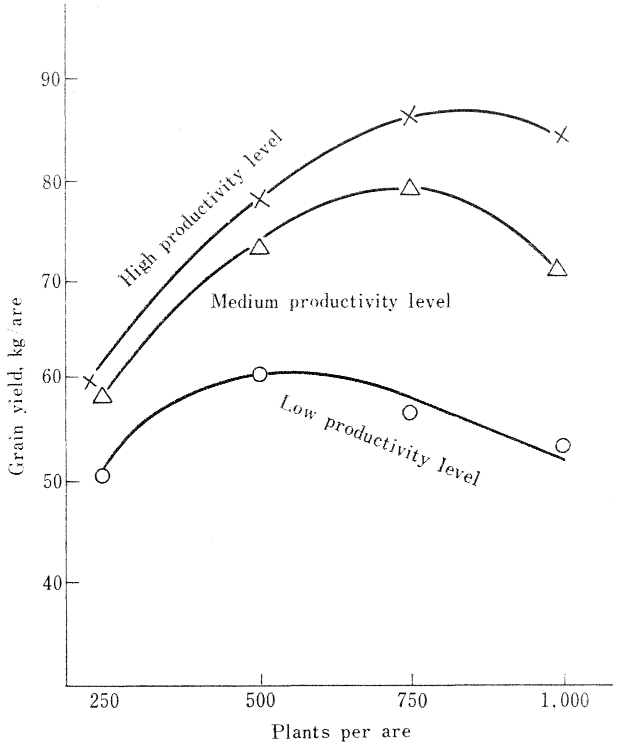

Fig. 1. Effect of plant populations and soil productivity levels on grain yields of maize.

that as soil productivity conditions become more favorable, the optimum stands required are higher and that the effects of stand on grain yields are much greater at high than at low productivity levels as Stringfield and Thacher pointed out.

2. A method for estimating maximum-yield populations:

In order to determine maximum-yield population, Duncan has provided a useful mathematical expression. He reported that as maize is planted at increasing populations the yield of the individual plant decreases and that there is a linear relationship between the logarithm of the average plant yield and the population. The formula for the relationship is expressed by equation (A) as follows:

$$\log y = \log K + bP \quad \text{or} \quad y = K \cdot 10^{bP} \qquad \text{(A)}$$

Where y is the yield per plant

K is a constant

b is the slope of the regression line

P is the population in plant per acre

Y is the yield per acre

The yield per acre is the product of the average yield per plant and the number of plants per *are* and a yield of 87 kg per *are* symbols as follows:

$$Y = yP \qquad \text{(B)}$$

Substituting the value of y from equation (A) gives:

$$Y = P \cdot K \cdot 10^{bP} \tag{C}$$

This equation gives the yield per acre in terms of the population.

If this equation is differentiated with respect to P and the result equated to zero and solved for P the result is:

$$P_{max} = \frac{-1}{2.303b} \tag{D}$$

Where P_{max} is the population that will give the maximum yield per acre.

We have attempted to apply the Duncan's equations to our plant population study on the three different productivity level soils mentioned previously. The results are shown in Fig. 2. The application of the Duncan's method was successful and three equa-

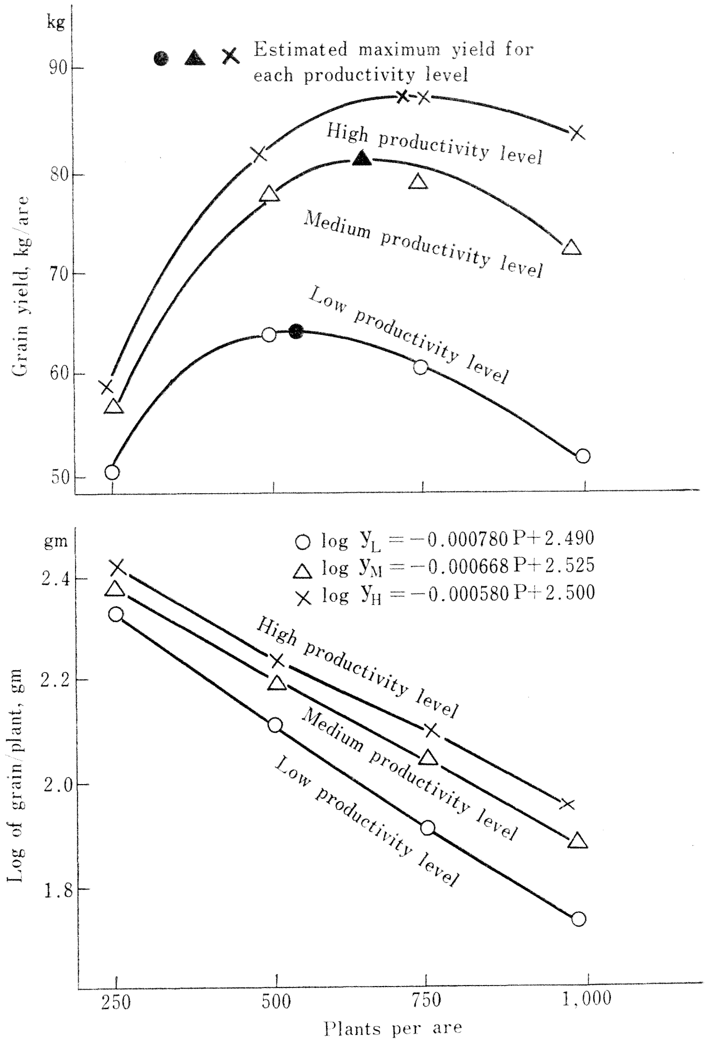

Fig. 2. Relationships between the logarithms of the yield per plant and population, and the corresponding yields per *are* and population.

tions for the three different productivity levels are given for estimating maximum yields and maximum-yield populations.

The effects of increasing soil productivity levels change the slope of the regression lines. The estimated maximum-yield populations were 557 plants per *are* and a yield of 63 kg per *are* on the low productive soils, 650 plants per *are* and a yield of 80 kg per *are* on the medium productive soils, and 749 plants per *are* and a yield of 87 kg per *are* on the high productive soils.

This indicated that increasing soil productivity increased the number of plants required for maximum yield.

3. A method for estimating the maximum-yield leaf area index (LAI):

Leaf area is one of the basic factors which determine crop yields. While considerable effort has been devoted to the determination of an optimum leaf area index for maize, both from the theoretical standpoint and from data based on actual yields

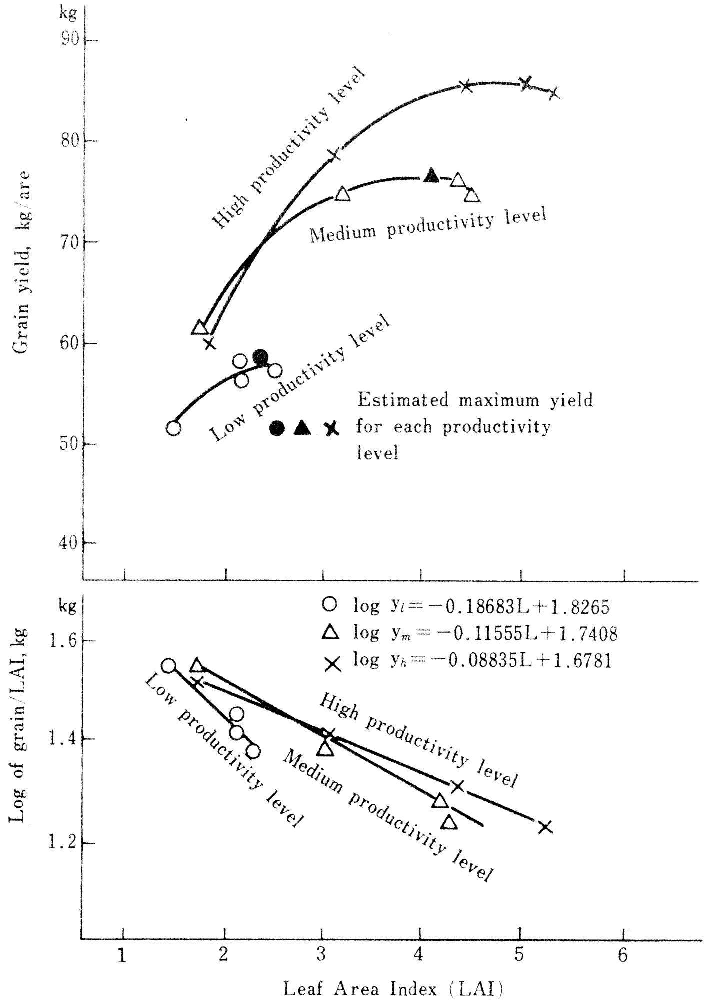

Fig. 3. Relationships between the logarithms of yield per LAI and the LAI, and the corresponding yields per are and the LAI.

in the field, as yet it has not been fixed. This section reports on the relationships found between the LAI and grain yields as influenced by differences in soil productivity.

The data are presented graphically in Fig. 3. The leaf area was measured at silking time. A linear relationship was found between the logarithm of the grain yield per LAI and the LAI. There was similar relationship between the average plant yield and the population as shown in Fig. 2. Therefore, using mathematical formulas from the previous section, the estimated optimum LAIs for the calculated maximum yields on the three soils were as follows: for maximum yield on the low productive soil, the optimum LAI was 2.32 with 57.4 kg per *are*, on the medium productive soil it was 3.76 with 76.1kg per *are*, and on the high productive soil 4.91 with 86.2 kg per *are*.

Thus, increasing the soil productivity increased the optimum LAI necessary for maximum yields, and it is believed that leaf area indexes above 4 are favorable for high grain yields.

Soil Improvement for High Grain Yields of Maize

An improvement in volcanic ash soils requires fundamentally an increase in the available phosphorus in the soils. Although for this purpose a heavy application of phosphorus fertilizer is indispensable, it is also essential that the fertilizer application does not make the phosphorus unavailable in the soil.

1. Effects of farm manure and phosphorus fertilizer applications on the maize grain yields on land with different cropping systems:

Maize was grown in fields using the following cropping systems: 1. maize-maize-

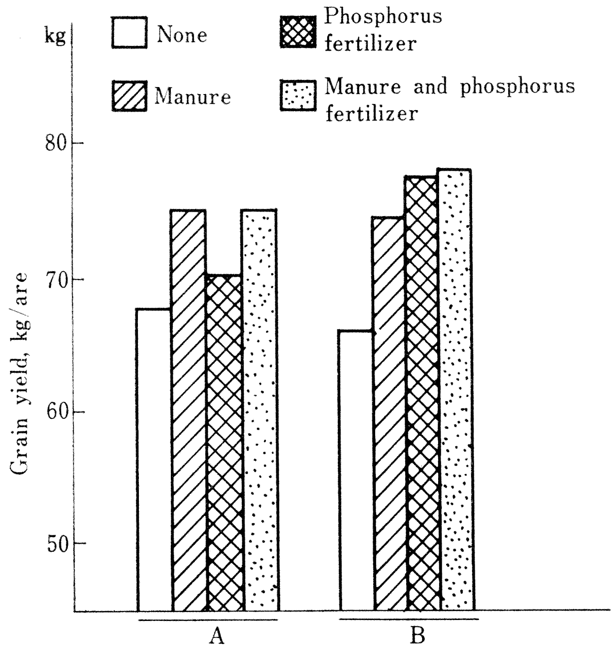

Fig. 4. Effects of the heavy application of manure and phosphorus fertilizer on grain yields with different cropping systems.

A: maize-maize-maize
B: soybeans-potatoes-maize

maize, 2. soybeans-potatoes-maize. After the establishment of the cropping systems, the third-year maize was evaluated. Manure at rates of 0 and 300 kg per *are* and phosphorus at rates of 1.5 and 4.5 kg per *are* were applied on both cropping systems every year.

As shown in Fig. 4, the greatest effects on maize grain yields were observed when a heavy phosphorus application and farm manure were used. On the continuous maize fields, the yiled was lower when the heavy application of phosphorus without farm manure was used than when manure alone was used. This may be due to insufficient nitrogen in the soil caused by a leaching loss of nitrogen as a result of the heavy phosphorus application.

The difference in the cropping systems affected the yields very little except for the heavy phosphorus application without manure on continuous maize. This suggests that when there are ample available nutrients in the soil, high yields may be obtained regardless of the cropping system.

2. An improved technique using a phosphate mixture for volcanic ash soils:

The effects of heavy applications of phosphatic fertilizer, using a phosphate mixture (4 parts of fused phosphate and 1 part of superphosphate) as devised by Yamamoto and Takahashi, on maize grain yields were tested using two volcanic ash soils (Kuriyagawa and Toshima soils). For an index showing the amount of the phosphate mixture to apply to the soils, the phosphorus absorption coefficients of the soils (Japanese method for measuring the phosphate retention activity of soil) were used.

At the beginning of the three year experiment, phosphorus (using the above phosphate mixture) was applied to the soils at 10% of their phosphorus absorption coefficients. This rate was 250 mg of P_2O_5 per 100 gm of soil for the Kuriyagawa soil and 229 mg of P_2O_5 per 100 gm of soil for the Toshima soil. The phosphate mixture was thoroughly mixed in the surface of the soils. Later a small amount of superphosphate (0.5 kg P_2O_5 per *are*) was applied in a band just before planting each year. The pH of

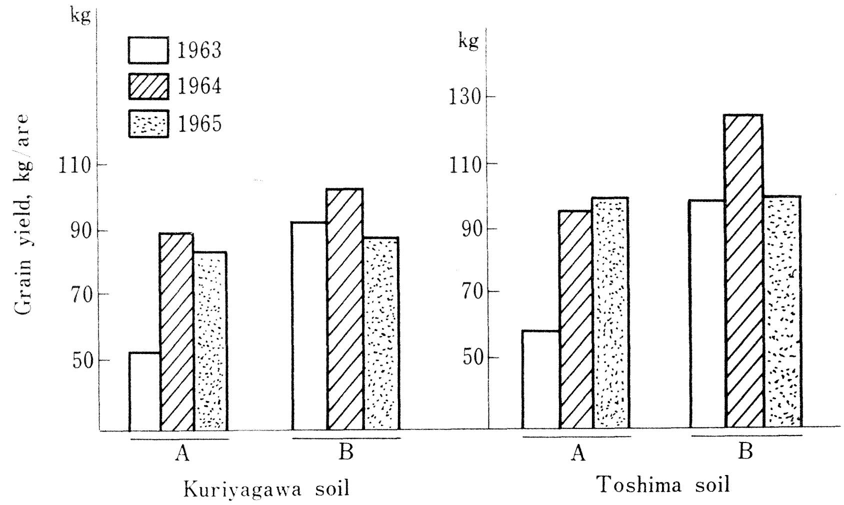

Fig. 5. Effects of heavy applications of phosphate mixture on maize grain yields on different soils.

A: Without phosphate mixture
B: With phosphate mixture

the phosphate mixture was 6.0 and as a result almost no change in the soil reaction was found following the heavy application.

By the application of the phosphate mixture, available phosphorus in the soils was increased and alliticity (activity of aluminum) of the soils was decreased. As a result, increased phosphorus uptake by the maize was observed and the total dry matter production of the maize was increased. As shown in Fig. 5, on both the Kuriyagawa and Toshima soils the higher grain yields were obtained by the heavy application of the phosphate mixture. When these yields are compared to those without the phosphate mixture, they are remarkable in the first and second year. However, there was little difference in yields in the third year following the application of the phosphate mixture.

It seems reasonable to assume that in the third year the nearly equal grain yields on both the soils, with and without the phosphate mixture application, depended upon decreased alliticity. Thus the available phosphorus was increased in the soils which had not been treated with the phosphate mixture. It is also probable that the heavy phosphorus application resulted in decreased nitrogen due to a leaching loss of rapidly mineralized nitrogen. Therefore, nitrogen applications should be increased after the second year of the phosphate mixture application.

Conclusion

A new technique for maize culture has been devised by the Tohoku National Agricultural Experiment Station as a result of recent research on maize culture for high yields in relation to soil improvement. Briefly, plant populations are adjusted to the productivity level of the soil, and greater plant populations on higher productive soils produce higher yields of maize grain.

We recommend that a plant population of 650 plants per *are* be grown and fertilizer be applied at the rate of 1.2–2.0 kg nitrogen, 1.5–4.5 kg phosphorus, and 1.5 kg potassium per *are*. Also, depending on the soil productivity, we recommend above 100 kg of farm manure per *are* be applied. The average grain yield last year at the station was approximately 80 kg per *are*. This was almost twice the yield as recent as a decade ago.

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Discussion

S. Hatta, Japan: How about the effect of heavy phosphorus application in economical standpoint?

Answer: According to our calculation about the experiment, the additional income subtracting the applied phosphate mixture expense from the returns of increased grain was approximately 18,000 yen/ha a year.

T. Yamada, Japan: In case of corn, the optimum LAI (leaf area index) seems to be about 9. The highest yield of your experiment was obtained in case of LAI 4–5. I think the population density is lower than usual. How do you think about this point?

Answer: I have never seen such a high LAI for grain corn. I think that the optimum LAI you said may be for fodder corn.

D. Sharma, India: What is the relationship between the leaf area index and optimum plant population required for high yield?

Answer: It is rather difficult to answer directly your question because LAI is varied with soil productivity. I think, however, that in our district it is better for high yielding corn cultivation to get LAI 5 with the plant population of approximately 65,000 plants/ha by regulating amounts of applied fertilizers.