18. BREEDING OF SHORT-TERM VARIETY OF MAIZE AND ITS ADAPTABILITY IN HOKKAIDO, JAPAN

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Introduction

Maize production in Southeast Asia countries, where climatic conditions are affected by the monsoon, should be basically considered on two cultivated types of crops, such as dry-(winter) and rainy-season (summer) crops. As rainfall can be one of the main limiting factors in production on river basins, breeding of excellent early maturing maize varieties, which are adaptable both for dry- and rainy-season crops, is necessary for escaping floods.

Hokkaido, where I am now studying, is located at the northern part of Japan, and it is snowy and cold in climatic conditions, and consequently, farming period is limited to only from 120 to 150 days there. Thus, as the primary limiting factor is temperature in Hokkaido, early maturing maize varieties, which are highly sensible to temperature, are under cultivation. Now, I will mention here of a part of my knowledges accumulated during fifteen years, from 1952 to 1966, when I had studied maize breeding in Hokkaido.

Breeding of Excellent Hybrids and Their Original Materials

Names of excellent recommended maize varieties (dent and flint types) in Hokkaido, and their released years are shown in Table 1. History of maize breeding works in Hokkaido is divided into two main periods: that is, the first period corresponds to the term from 1905 to 1938, when "open-pollinated varieties" were introduced from the U.S.; while, in the second period, from 1945 to the present, introduction and breeding of "hybrids" have been carried out.

As I had participated in this work since 1952, I mention here of recommended hybrids Ko No. 4 and Ko No. 6, which were released in 1957 and 1962, respectively. I leave out Ko No. 504 released in 1962, because it was the introduction of "Ohio W64" bred at the Ohio Agricultural Experiment Station in the U.S., and then, was tested on its adaptability in Hokkaido. Among parental lines of Ko No. 4, three-way cross hybrid, "N21" and "N19" as seed parental lines, which belong to "North American Type", are inbred lines selected from population of "Sakashita" improved through mass selection from flint variety introduced from the U.S.. While, "T6" as pollinator is an inbred line selected from population of "Mais Peta", which is local variety in Italy, and also, belongs to "European Type", seeming to be derived from the cross between "Aegean Type" and "Caribbean Type".

In Ko No. 6, double cross hybrid, "D403" and "D405" as seed parental lines are the selection from the population of dent hybrid introduced from Pride Hydrid Co. in the U.S., and belong to "North American Type"; while, "T102" and "T107" as pollinators are the selections from the population of local flint variety named "Koshu" at piedmont

Table 1. Recommended maize varieties in Hokkaido, Japan.

	Released year	Name of variety (Flint)	Released year	Name of variety (Dent)
Open-pollinated variety	1905 1905	Sapporo-hachigyo (E) Long Fellow (M)		
			1923 1923	Yellow Dent Corn (EL) White Dent Corn (EL)
	1924 1938	Extra Early Flint (EE) Sakashita (E)		
Hybrid	1945	Sapporo Ko No. 130 (E) (Sakashita × Mais Peta)		
			1952	Ko No. 503-IOWA 4417 (M) (B8 × Ia153) (WF9 × M14)
	1957	Ko. No. 4 (E) (N21 × N19) × T6		
			1962	Ko. No. 6 (M) (D403 × D405) (T102 × T107)
			1962	Ko. No. 504-OHIO W64 (L) (Oh51A × WF9) (Oh43 × Oh45)

Maturity: EE—Extra Early, E—Early, M—Mid-Season, L—Late, EL—Extra Late
Pedigree of Inbred Lines: N21, N19—Sakashita (Hokkaido Local Variety, JAPAN)
T6—Mais Peta (Local Variety, ITALY)
D403, D405—Pride Hybrid Co. (U.S.A.)
T102, T107—Koshu (Honshu Local Variety, JAPAN)
Oh51A, WF9, Oh43, Oh45—Ohio Agr. Exp. Sta. (U.S.A.)

of Mt. Fuji, and belong to "Caribbean Type".

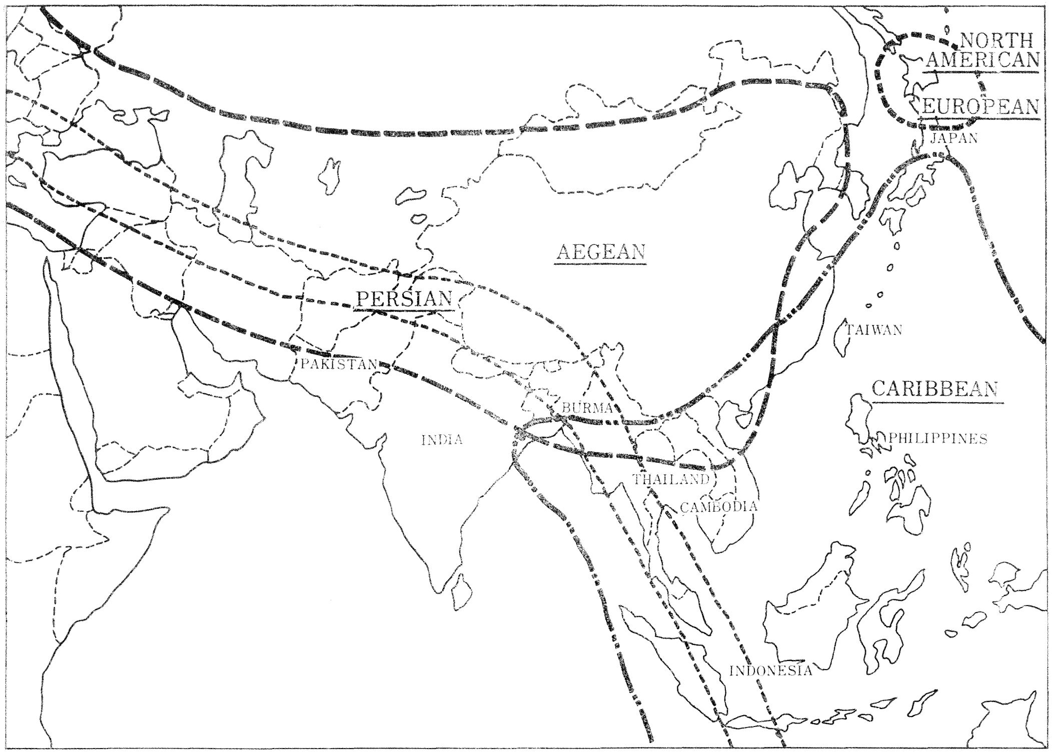
Thus, I think that these two hybrids having high combining ability could be bred by using combinations between diverse origins of different types in early maturity, such as between "North American Type" and "European Type" or "Caribbean Type", as materials.

Fig. 1 is cited from "Studies on the characteristics of local varieties in Japan" written by T. Suto and Y. Yoshida in **1959**. This shows five types of the Oriental maize, such as "North American", "European", "Aegean", "Persian" and "Caribbean", and also, their geographical distributions. Besides these, "Persian Type" is also early in maturity, and there seem to be some varieties distributing at high latitude or altitude in "Aegean Type" and "Caribbean Type". Therefore, in maize breeding in Southeast Asia, collection of materials distributing in these areas and investigation of their characteristics seem to be desirable.

Adapting Areas of Improved Hybrids in Hokkaido

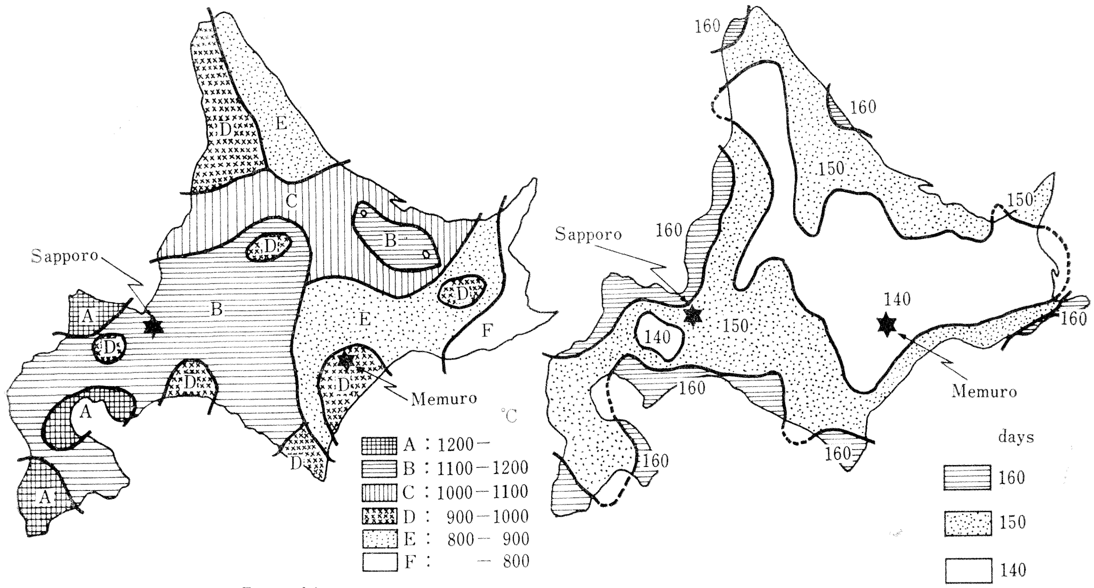
As above mentioned, temperature is the primary factor in maize growth in Hokkaido. And I divided the adaptation belts of maize varieties in Hokkaido, based on the formula "Effective Integrating Temperature—E.I.T.". The calculating method is as follows:

$$\text{E.I.T.} = \sum_{\text{Date of planting}}^{\text{Date of harvesting}} (\text{Mean temperature } -10^{\circ}\text{C})$$



After T. Suto and Y. Yoshida (1959)

Fig. 1. Geographical distribution of the Oriental Maize.



$$\text{E.I. Temperature} = \sum_{\text{Date of plant.}}^{\text{Date of harvest.}} (\text{Mean Temperature} - 10°\text{C})$$

Fig. 2. Effective integrating temperature belts (left) and non-frost season belts (right) in Hokkaido, JAPAN.

Table 2. Growth and yield test of recommended maize hybrids in Hokkaido, Japan. (1961–1967)

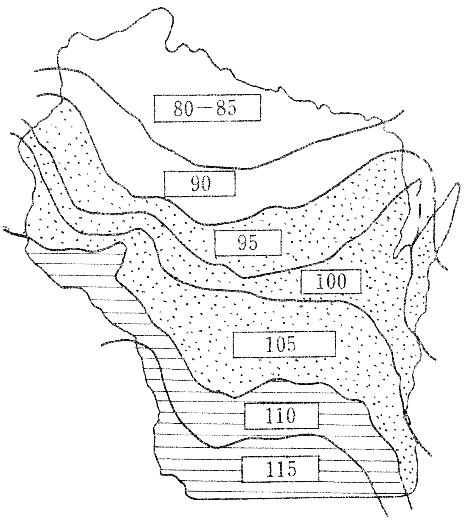
Name of hybrid	Date of plant.	Date of germ.	Date of tassel.	Date of silk.	Date of maturity	Grow. days	Culm height (cm)	Ear length (cm)	Grain yield (kg)	Effect. Int. Temperature (°C)
Ko No. 4	May 17	June 1	July 30	Aug. 5	Sept. 25	131	199	18.8	557	980–1,070 (1,000)
Ko No. 6	May 17	May 31	Aug. 5	Aug. 11	Oct. 10	146	245	18.5	627	1,070–1,110 (1,100)
Ko No. 504	May 17	June 1	Aug. 6	Aug. 13	Oct. 14	150	214	17.3	585	1,090–1,230 (1,200)

Adaptation of maize hybrids for effective integrating temperature belts.

Name of hybrid	From planting to germination	From germination to silking	From silking to maturity	Total (°C)	Belt of adaptation
Ko No. 4 (E)	50	550	400	1,000	D, E
Ko No. 6 (M)	50	630	420	1,100	C
Ko No. 504 (L)	60	640	500	1,200	A, B

This idea, which was presented by C. A. Magoon and C. W. Culpepper in the U.S. in 1926 to judge the maturity of sweet corn varieties, was based on the thinking that the temperature less than 10°C did not contribute to maize growth, and only rainfall during maturing period might disturb the value given by the above formula.

Fig. 2 shows the comparison of two area divisions, one of which is based on the division into six classes, of range from 1,200 to 800°C in the E.I.T., and another of which into three classes of range from 140 to 160 growing days in non-frost season



Based on the average length of maize growing season in days, this map shows the major maturity belts for maize in Wisconsin. The Wisconsin Experiment Station has developed a number of hybrids to fit the wide range of climatic and soil conditions of the state.

General adaptation of Wisconsin maize hybrids for grain production for the several maturity zones of Wisconsin.

Relative maturity			Hybrids for grain
Upper Zone	80	Early	W240, W255
	85	Medium early	W270, W275—W279
	90		W335, W341—W355
	95	Medium	W416, W416A, W416AA
Middle Zone	95	Early	W416, W416A, W416AA
	100	Medium early	W464, W464A
	105		W525, W531
	110	Medium	W570, W595, W606
Lower Zone	100	Early	W464, W464A
	105	Medium early	W525, W531
	110		W570, W595, W606
	115	Medium	W641AA
	120	Late	W643, W692, W685

Fig. 3. Maize maturity belts in Wisconsin, U.S.A.

adopted customarily up to the present. I think that the area division based on the growing days would be well adaptable under the climatic conditions like in the Corn Belt in the U.S., but the E.I.T. would be more reasonable than the above, in the case that the maize growth is delayed by continuous low-temperature in the summer, which frequently has occured in Hokkaido.

Table 2 shows the growth, yields, and also, adapting areas based on the E.I.T., of the above three hybrids. That is, the adapting area of Ko No. 4 corresponds to "D" and "E" belts being 980–1,070°C in the E.I.T.; and Ko No. 6 does to "C" belt in 1,070–1,110°C; and also, KO No. 504 does to "A" and "B" in 1,090–1,230°C.

Area Division for Adaptation of Hybrid in the U.S.A.

I scrutinized the methods, by which the adapting areas of hybrid in the U.S.A. have been decided, as reference data for the area division for adaptation of improved hybrids in Hokkaido. Consequently, I can introduce here the differences in the above methods between in the North and in the South in the U.S.A..

Fig. 3 shows the maturity belts for maize adaptation in Wisconsin, located in the North in the U.S.A.. Here, growing days ranging from 80 to 120 days are divided into five classes, and the adapted hybrids in each class are shown by the corresponding numbers. I divided the adaptation belts by the E.I.T. for each hybrid in Hokkaido, instead of the growing days mentioned above.

Fig. 4 shows the area division for maize adaptation in Texas, located in the South in the U.S.A.. In this state, as temperature is not a limiting factor as in the North, eleven soil areas and six rainfall belts ranging 10–50″ are set up. And, the area division on the basis of planting dates, by which two months ranging from February 15 to April 15 is divided into five belts, is made for the maize growing areas, where the rainfall is 30″ or more. This thinking seems to be suggestive for maize production in Southeast Asia.

Cultivation Tests in Hokkaido

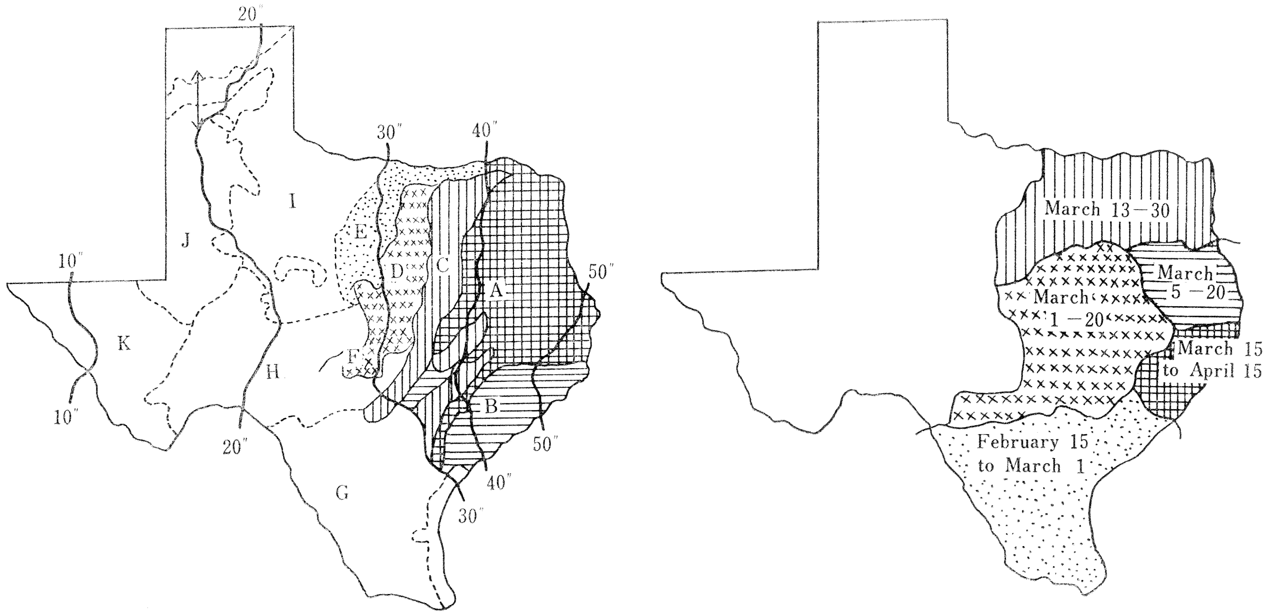
"Sakashita", open-pollinated variety, was released in 1938, and after then, an improved hybrid Ko No. 4 was bred in 1957 to take the place of "Sakashita". In 1960, cultivation tests for comparison of these two varieties were carried out. The tests were set up by treatments of fertilizers, in which standard- with N:7.94, P_2O_5:10.00 and K_2O_5:5.00 kg per 10a, and twice standard-fertilizing plots were set, and of plant populations, which consist of 3,700, 5,600, 7,400 and 11,100 plants per 10a, respectively.

According to the results shown in Table 3 and Fig. 5, the most remarkable differences between these two varieties were the changes of their yields. That is, "Sakashita" showed the highest grain yield with 5,600 plants per 10a in the standard-, and with 7,400 plants in the twice standard-fertilizing plots, respectively. This showed that Ko No. 4 might have higher possibility in grain yield increase under conditions with quantities of plant populations and of fertilizers than "Sakashita"; and also, the limitation for grain yield per 10a was 446 kg in "Sakashita", while, 574 kg in Ko No. 4.

Ecological Variation of Ko No. 4 in Hokkaido

Hokkaido is located at the northern part of Japan, and there are some regions having their specialities in climatic and soil conditions even in this island, because it is surrounded by three seas, such as the Pacific Ocean, the Sea of Okhotsk, and the Sea of Japan, and also, is divided into some regions by mountains.

I will introduce here the results of the tests carried out at Sapporo and Memuro,



Soil Areas

A : East Texas Timber Country
B : Gulf Coast Praine
C : Blackland Praine
D : Grand Praine
E : West Cross Timbers
F : Central Basin
G : Rio Grande Plains
H : Edwards Plateau
I : Rolling Plains
J : High Plains
K : Mountains and Basins

Fig. 4. Rainfall belts and soil areas (left) and recommended planting dates for the maize-growing areas (right) in Texas, U.S.A..

Table 3. Yield test of grain corn. (Variety × Fertilizer × Plant Population)

Name of variety	Fertilizer	Plant population (plant/10a)	Plant height (cm)	Date of maturity	Ear length (cm)	100 Kernal weight (g)	Grain weight (kg/10a)	Ratio (A) (%)	Ratio (B) (%)
Sakashita (open-pollinated variety)	Standard (kg/10a)	3,700	225	Sept. 21	20.3	31.2	313	100	100
	N: 7.94	5,600	230	〃 20	18.2	29.7	388	124	124
	P: 10.00	7,400	231	〃 21	17.2	27.8	377	120	120
	K: 5.00	11,100	231	〃 20	13.7	25.4	344	110	110
	2×	3,700	229	Sept. 20	20.9	30.9	328	105	105
		5,600	239	〃 20	17.6	28.5	379	121	121
		7,400	249	〃 20	16.5	27.1	446	143	143
		11,100	237	〃 19	14.5	26.0	404	129	129
Ko No. 4 (hybrid)	Standard	3,700	254	Sept. 25	17.7	31.0	361	100	115
		5,600	257	〃 25	16.8	29.7	505	140	161
		7,400	250	〃 25	14.7	28.2	507	140	162
		11,100	252	〃 25	11.9	25.9	395	109	126
	2×	3,700	263	Sept. 28	18.2	30.7	392	109	125
		5,600	261	〃 27	16.0	29.5	469	130	150
		7,400	259	〃 27	14.6	29.6	556	154	178
		11,100	251	〃 27	12.9	27.1	574	159	183

Sapporo, Hakkaido, JAPAN.

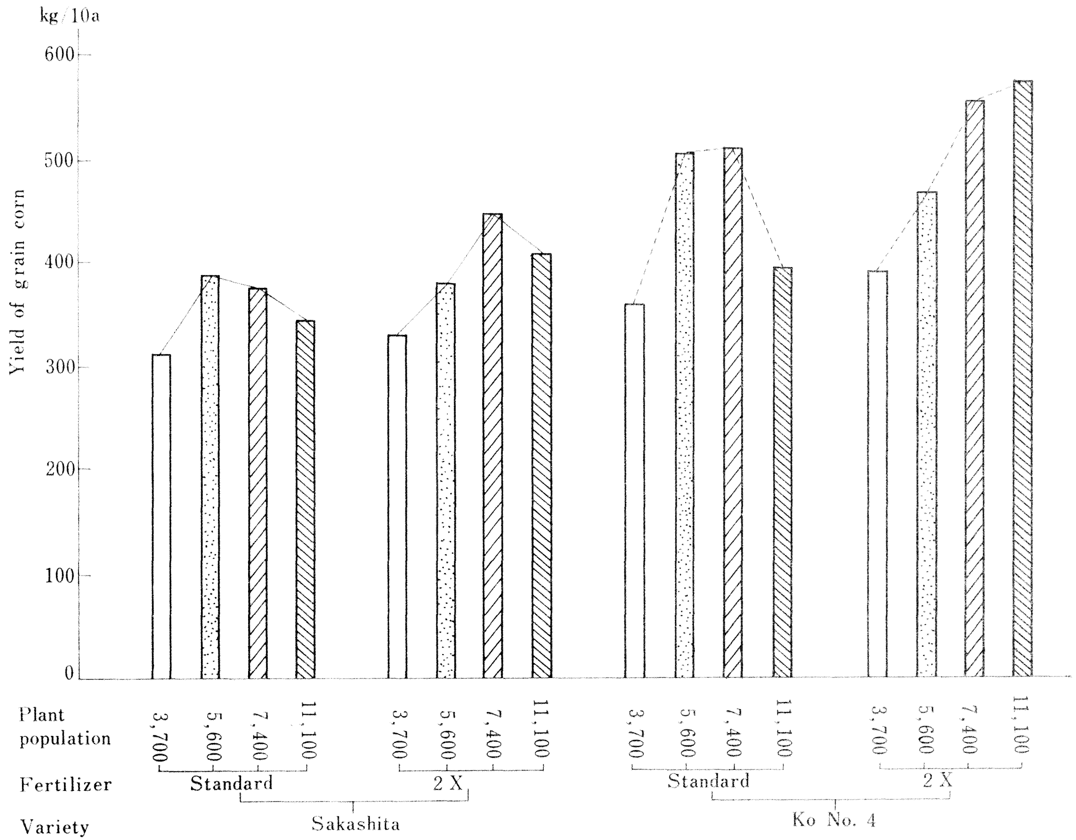


Fig. 5. Yield test of grain corn. (Variety × Fertilizer × Plant Population)

Table 4. Weather Table: Temperatures (°C) in Sapporo and Memuro, Hakkaido, JAPAN. (1963)

Mean atmosphore temperature							Soil temperature (5 cm below surface)						
Month	*	Sapporo	Memuro	Month	Sapporo	Memuro	Month	*	Sapporo	Memuro	Month	Sapporo	Memuro
May	1	8.2	7.0	May B	9.5	9.6	May	1	7.2	9.3	May B	8.7	9.8
	2	10.2	10.8	M	13.6	14.0		2	10.1	10.7	M	12.3	13.3
	3	13.7	13.4	E	14.6	14.7		3	11.8	12.5	E	13.8	14.3
	4	12.9	12.9	June B	11.7	10.1		4	12.8	14.0	June B	13.7	11.4
	5	13.9	14.8	M	16.9	16.8		5	13.2	14.0	M	16.4	16.8
	6	14.5	15.6	E	17.6	17.5		6	14.4	14.5	E	17.1	18.0
June	1	11.8	9.4	July B	20.6	19.0	June	1	14.0	11.5	July B	20.6	20.5
	2	12.2	10.3	M	18.6	17.6		2	13.3	11.3	M	19.8	19.0
	3	16.7	16.5	E	24.4	21.7		3	15.5	16.2	E	21.2	21.2
	4	17.4	15.8	Aug. B	23.7	22.2		4	17.0	17.5	Aug. B	23.6	23.0
	5	15.3	14.8	M	22.0	20.0		5	16.1	16.7	M	22.5	20.9
	6	19.8	19.7	E	20.6	20.0		6	18.0	19.2	E	20.1	20.5
July	1	21.2	18.3	Sept. B	17.0	18.0	July	1	20.4	20.1	Sept. B	18.4	19.1
	2	19.6	20.0	M	14.2	14.4		2	20.8	20.9	M	14.3	16.3
	3	19.9	20.6	E	12.6	13.6		3	21.2	21.0	E	12.4	14.2
	4	17.1	14.5	Oct. B	11.9	11.3		4	18.4	17.0	Oct. B	11.4	12.2
	5	20.5	18.6	M	9.0	9.8		5	20.1	18.9	M	8.6	9.6
	6	24.5	23.4	E	8.9	8.2		6	22.0	23.0	E	7.6	8.0

Note: 1. B; Begining of month, M; Middle of month, E; End of month.
2. *; Period of 5 days.

Table 5. Local variation in some characters of Ko No. 4 in Sapporo and Memuro, Hokkaido, Japan.

	Date of planting		Date of germination		Date of silking		Date of maturity		Dry matter weight			
									40 days after plant.		60 days after plant.	
	Sapporo	Memuro	Sapporo	Memuro	Sapporo	Memuro	Sapporo	Memuro	Sapporo (g/plant)	Memuro (g/plant)	Sapporo (g/plant)	Memuro (g/plant)
Early plant.	May 7	May 7	May 23	May 22	Aug. 4	Aug. 5	Sept. 29	Sept. 24	0.42	0.50	0.377	8.70
Ordinary 〃	May 17	May 17	May 30	May 29	Aug. 6	Aug. 5	Oct. 6	Sept. 27	0.49	0.46	0.292	26.00
Late 〃	May 27	May 27	June 9	June 11	Aug. 8	Aug. 6	Oct. 8	Sept. 29	1.42	3.56	3.150	29.00

	Plant height		Ear length		100 Kernel weight		Grain yield	
	Sapporo (cm)	Memuro (cm)	Sapporo (cm)	Memuro (cm)	Sapporo (g)	Memuro (g)	Sapporo (kg/10a)	Memuro (kg/10a)
Early Plant.	220	220	16.6	16.6	33.9	35.1	586	633
Ordinary 〃	216	222	17.8	18.4	34.4	34.4	539	519
Late 〃	212	239	17.6	18.3	32.9	34.2	506	463

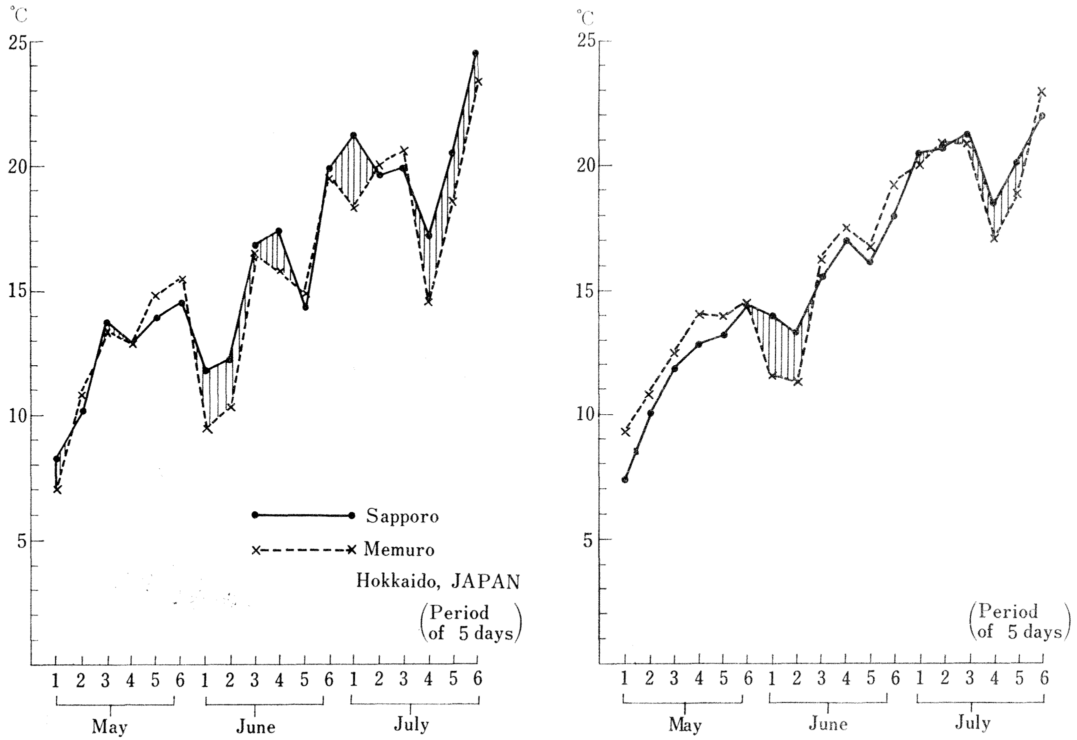


Fig. 6. Mean atmospheric (left) and soil (right) temperature (1963).

Note: Soil temperature was taken at 5cm below the soil surface.

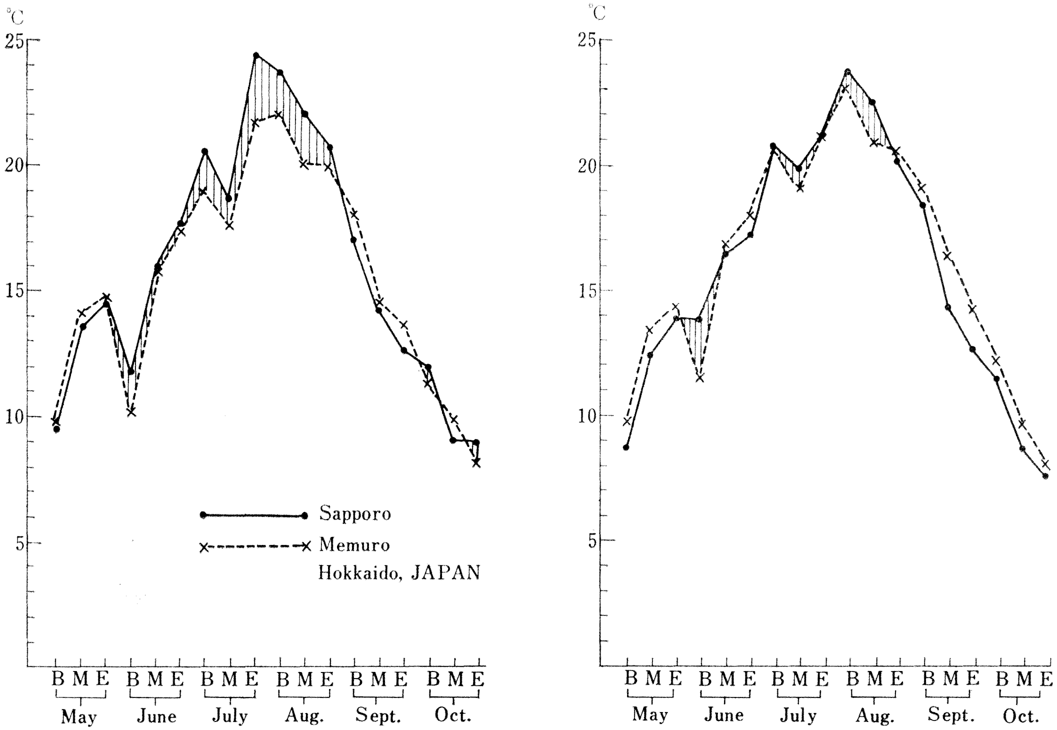


Fig. 7. Mean atmospheric (left) and soil (right) temperature (1963).

Note: Soil temperature was taken at 5 cm below the soil surface.

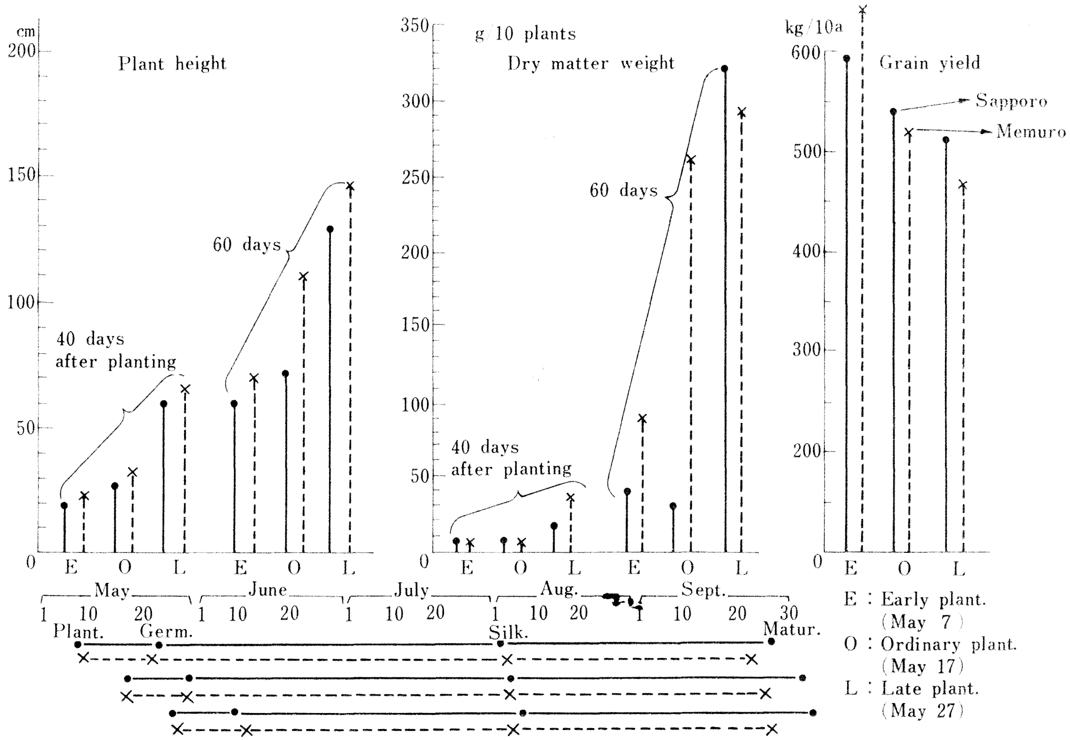


Fig. 8. Local variation in some characters of Ko No. 4 between in Sapporo and in Memuro, Hokkaido, JAPAN. (1963)

which are located at the central and the eastern parts of Hokkaido, in 1963. In this tests, Ko No. 4 was used and three different planting dates, such as early (May 6), ordinary (May 17) and late (May 27) planting, were set to know how maize plants showed their ecological variation under different conditions.

Table 4, and Fig. 6 and 7 show the mean air and soil temperatures, which were generally rather lower at Memuro than at Sapporo, but at young stage of maize growth during May to June. Table 5 and Fig. 8 show the ecological variation of Ko No. 4 between at two tested places. More plant height and more dry matter weight at the young stage of maize growth at Memuro resulted in higher yield. This was shown by the results that grain yield in the early planting plot at Memuro showed the highest of 633 kg per 10a among all, but less at Memuro than at Sapporo both in the ordinary and the late planting plots. This is my ground of thinking that maize production at the eastern part of Hokkaido has advantage, which early planting and subsequent better growth at young stage can be closely connected with yield increase, and accordingly, that Memuro or the eastern part of Hokkaido is the region having high possibility for yield increase in maize production.

I mentioned here of the following four knowledges, which I had obtained from my experiences through maize breeding in Hokkaido.

1) Breeding materials.
2) Thinking for regional extension of the improved hybrids.
3) Differences between the improved hybrids and the old varieties.
4) Ecological variations of the hybrids in Hokkaido.