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Adaptation of silage maize varieties under extreme northern growing condions in Finland

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Abstract. Trials with maize varieties from various places in the world were started in 1975. In preliminary trials in 1975, 280 varieties were tested. Between 19 and 23 varieties were selected for ordinary variety tests in 1976—78 at the University farm in Siuntio.

Weather conditions, particularly average daily temperatures in 1975 were better than the long term averages, and in 1976—78 far below the average growing conditions.

Dry matter yields of the seven harvested silage varieties in 1975 varied between 5.8 and 11.5 tons/ha. In 1976—78 the variation in DM yields was 3.8—8.0 tons/ha among 19—23 varieties. In 1975, 44 varieties out of 280 produced mature seed. Only one variety matured in 1978, but none in 1976—77. The developmental stage of silage maize is primarily determined by ear percentage and secondarily by DM %. In 1975 the average ear % of seven varieties was 49.1 %, in 1978 18.1 % and in 1976—77 only 4.0—5.7 % in DM.

As a result of the variety tests promising varieties from Yugoslavia, France and Germany could be found. It can be concluded from the long term temperature data that with very early hybrid varieties a mature grain yield can be harvested twice in ten years. Good quality silage material can be harvested six times in ten years and a satisfactory crop can be obtained eight times in then years.

The limiting factor for the growth and development of maize in Finland is the low average temperature of the growing season. Important but less significant is the length of the vegetative period, which is determined by the first killing frost in the fall. The temperature deficit is particularly critical at the beginning of the growing season.

Introduction

The adaptability of maize varieties to Finnish climatic conditions was first studied in the 1930's. The most important results were published by A. I. Virtanen. According to Virtanen the fresh weight of the best maize variety varied between 64—107 tons/ha, the average yield being 72.5 tons/ha (VIRTANEN 1938). At this time silage maize was widely cultivated on private farms. VIRTANEN's data, obtained from 131 farms in 1937, summarizes the average fresh yield of maize at 41 tons/ha (VIRTANEN 1938).

At the Plant Breeding Institute of Hankkija in Tammisto maize varieties have been studied since the early 1930's. In 1953—54 the fresh yield of silage maize varieties varied between 36—80 tons/ha. The average fresh weight of varieties was 54 tons/ha. The dry matter percentage (DM %) was about 11.7—13.6 and the harvested yield about 7.5 tons DM/ha. In 1955 in Tammisto maize suffered from drought and the fresh yields reached only a level of 9—22 tons/ha. In 1957—58 in Tammisto the yields were between 46—83 tons/ha (RAVANTTI 1956, 1960). In later research program the average dry matter yields of silage maize varieties varied between 5.4—6.8 tons/ha in 1965—69 and between 5.3—10.6 tons/ha in 1973—74 (RAININKO 1970, JUUTI and RAININKO 1975).

At the Agricultural Research Center in Tikkurila maize trials were carried out already in the 1930's but were interrupted during the war. In 1950 they were resumed in connection with the FAO hybrid maize program. These trials were mainly carried out by the Dept. of Plant Husbandry in Tikkurila and three experimental stations in southern Finland. Yields varied widely in various years and were generally low (YLLÖ 1962). In 1937 the variety tests showed a yield variation of 17.7—54.1 tons/ha the average yield of all varieties being 31.2 tons/ha. In 1950, 1952—53, 1956 and 1958 the trials failed more or less completely mainly because of cool growing seasons, early autumn frosts and the use of largely nonadapted varieties.

Maize variety trials in the 1950's and in the early 1960's showed that maize was an uncertain field crop under Finnish conditions. However, it was concluded that it can be grown with certain limitations in South Finland, principally on fertile, warm soils, where there is little danger of autumn frosts (YLLÖ 1962).

As a result of favorable development of hybrid maize breeding in Central Europe during the last ten years, the economic northern limit of maize growing has been moved to northern Germany and Denmark. Due to this development a new start in maize research was made in 1975 in Finland. The new survey of maize production in Finland began with the testing of large collections of breeding material from all over the world. Subsequently this material has been tested under different cultivation conditions. The research was financed by the Cultural Foundation of Finland in 1975—77 and the Ford-Foundation in 1978.

Materials and methods

The preliminary variety tests were established on the Wiurila farm in Halikko near Salo in 1975. A collection of 280 varieties was tested in one replication. This screening nursery served the purpose of selecting promising material from a world wide collection of potential maize lines and varieties.

In subsequent years (1976—78) the experimental desing was a randomized block with 4 replications. This was carried out on the Suitia Helsinki University farm:

	Screening nursery 1975	Variety trials 1976	1977	1978
Varieties	280	19	20	23
Replications	1	4	4	4
Plot size m^2	16	48	26	16
Fertilization kg/ha (15—15—15)	1 000	1 000	1 000	1 000
Seeding date	May 5	May 17	May 12	May 17
Plants/m^2	10	10	10	10
Row spacing cm	80	80	80	80
Plant spacing cm	12.5	12.5	12.5	12.5
Seeding depth cm	7	7	7	7
Weed control date	May 20	June 2	May 20	May 23
Irrigation mm	2 × 25	2 × 25	25	25
Harvest date	Oct. 27	Oct. 6	Sept. 24	Sept. 23

A two-unit drill (Kleine Maxicorn) was used as a seeding unit. Fertilizer was applied to both sides and below the seed. The plots were pre-emergence weed-controlled with Gesaprim-50, 3—4.5 l/ha. Insects were controlled with Roxion 0.8 1/ha. The yield data consisted of the fresh weight, dry matter %, and protein content (%) in dry matter. Height measurements were taken once a week during the growing season.

Weather conditions

Temperature conditions during the growing seasons 1976—78 were generally below long-term averages for 1931—60 (Table 1). The year 1975 represents an above normal growing season, which resulted in a well matured high grain yield. Especially the warm and long autumn in 1975 boosted the growth and development of the maize plant.

During the whole research period the precipitation stayed below the long term average (Table 1). The maize was irrigated every spring after emergence and a second time before flowering in 1975—76.

During the growing seasons 1975—78 the last harmful frosts occurred during the time of May 29 — June 18 (Table 1). These night frosts were harmful for the growth but did not kill the crop. The autumn frosts (—2° C) in 1976—77 stopped the growth of maize in early September.

The growing seasons 1975—78 represent 170—130 growing days from the seeding date to the harvest (Table 2). Calculated degree days show the levels between 2 237° C and 1 667° C. If expressed in effective degree days for maize (t°—10° C) the levels are between 688° C and 412° C. Calculated corn heat units (CHU) as shown by Brown (1975) 2 259° C and 1625° C do not differ very much from the degree days.

Table 1. Weather conditions in the experimental area in 1975–78.

Period	Years 1975	1976	1977	1978	Avg. 1930–60
	Avg. daily temperature °C				
May 1 – 30	11.6	10.2	9.4	9.3	9.0
May 30 – June 29	12.9	12.6	13.8	14.2	14.2
June 30 – July 29	17.0	15.0	14.3	14.5	16.8
July 30 – Aug. 28	16.7	13.5	13.8	13.6	14.9
Aug. 29 – Sept. 27	13.6	8.7	8.2	8.8	9.9
Avg.	14.4	12.0	11.9	12.1	13.0
	Precipitation mm				
May 1 – 30	40	14	16	6	39
May 31 – June 29	29	51	40	52	46
June 30 – July 29	38	40	94	70	73
July 30 – Aug. 28	40	58	58	82	75
Aug. 29 – Sept. 27	60	68	64	75	65
Total	207	231	272	285	298
	Killing frost				
Spring 0.0° C	3/6	10/6	2/6	18/6	
(last) –2.0° C	30/5	29/5	1/6	18/6	
Autumn 0.0° C	9/10	22/8	19/8	14/8	
(first) –2.0° C	10/10	8/9	9/9	21/9	

Table 2. Growing days, degree days (DD), effective degree days (EDD) and corn heat units (CHU) of growing seasons 1975–78 in southern Finland.

	Year 1975	1976	1977	1978	Avg.
Growing days	170	143	136	130	145
Degree days (DD) °C	2 237	1 667	1 679	1 714	1 824
Effective degree days (EDD) °C	688	412	433	455	497
Corn heat units (CHU) °C	2 259	1 656	1 625	1 699	1 810

$DD = \Sigma$ (Avg daily °C)

$EDD = \Sigma$ (Avg daily °C – 10 °C)

$$CHU = \Sigma \frac{(\text{Daily Y max} + \text{daily Y min})^{1)}}{2}$$

1) $Y\ max = 3.33\ (T\ max - 10) - 0.084\ (T\ max\ 10)^2$

$Y\ min = 1.8\ \ (T\ min - 4.44)$

Results and discussion

Yields

Under temperature conditions above average, as in 1975, 44 of the studied 280 varieties produced a matured grain. The seven best varieties showed approximate yield levels of 5.8–11.5 tons total dry matter (DM)/ha (Table 3). Total protein yields varied between 580 and 940 kg/ha. The grain yields of the seven varieties varied between 3 279 kg/ha and 5 578 kg/ha. The total DM yields obtained in 1975 in Wiurila are similar to the Danishr esults (PEDERSEN 1975).

Table 3. Total yields, matured seed yields and dry matter content, protein content in DM and the amount ot cars in the total yield in 1975 in southern Finland.

Variety	Total yield tons/ha			Matured	Content %		
	Fresh	DM	Prot.	Grain kg/ha	DM	Prot.	Ears
LG 11	44.9	11.4	.86	5 578	25.5	7.6	53.6
LG 5	41.9	11.5	.83	5 550	27.4	7.3	52.5
LG 672508	39.5	11.0	.94	4 955	28.0	8.6	43.1
LG 775007	38.0	10.0	.89	4 828	26.4	8.9	46.0
LG 7	37.5	10.2	.76	4 659	27.2	7.5	50.2
CP 170	37.2	8.7	.76	3 930	23.3	8.8	—
Flash	22.0	5.8	.58	3 279	26.3	10.0	—
Avg.	37.3	9.8	.80	4 683	26.3	8.4	49.1

In 1976 under clearly unfavorable growing conditions the average total fresh and DM yields of 19 varieties were 34 tons/ha and 5.7 tons/ha (Table 4). The variation in fresh yields of all varieties was 23.8—44.8 tons/ha and in dry matter yields 3.9—7.4 tons/ha. Protein yields of all varieties averaged 630 kg/ha.

Table 4. Fresh weight, dry matter (DM) and protein yields and DM, protein and ear content (%) of silage corn varieties in southern Finland in 1976.

Variety	Yields tons/ha			Content %		
	Fresh wt	DM	Prot.	DM	Prot.	Ears
LG 11	44.8^{c}	7.4^{c}	.81^{c}	16.6^{ab}	10.9	4.0
HIT	40.3^{bc}	6.9^{bc}	.75^{bc}	17.1^{ab}	10.9	7.0
Hansa	39.1^{bc}	6.7^{bc}	.75^{bc}	17.0^{ab}	11.3	8.7
LG 9	38.2^{bc}	6.6^{bc}	.74^{bc}	17.4^{ab}	11.2	3.0
LG 7	38.3^{bc}	6.3^{bc}	.68^{bc}	16.3^{ab}	10.8	6.7
Rubis 9	35.8^{b}	6.2^{bc}	.64^{bc}	17.6^{ab}	10.3	3.6
Prior	40.2^{bc}	6.1^{bc}	.69^{bc}	15.2^{a}	11.4	2.1
CP 170	33.3^{b}	6.0^{bc}	.68^{bc}	18.0^{b}	11.4	3.3
LG 5	33.8^{b}	5.8^{bc}	.66^{bc}	17.2^{ab}	11.4	2.6
ACG 200	36.9^{bc}	5.8^{b}	.65^{bc}	15.7^{ab}	11.3	3.2
Zelder 75—102	33.6^{b}	5.6^{b}	.62^{b}	17.0^{ab}	11.0	7.6
Flash	34.3^{b}	5.6^{b}	.61^{ab}	16.4^{ab}	10.9	6.0
EDO	30.6^{ab}	5.4^{ab}	.64^{bc}	17.4^{ab}	11.9	8.8
Velox	33.4^{b}	5.3^{ab}	.56^{ab}	15.9^{ab}	10.6	3.8
ACG 188	32.5^{b}	5.0^{ab}	.60^{ab}	15.6^{ab}	12.0	3.2
Jacques Cartieur	27.5^{ab}	4.7^{ab}	.54^{ab}	17.4^{ab}	11.5	4.2
Zelder 75—104	25.9^{ab}	4.4^{ab}	.44^{a}	17.0^{ab}	9.9	2.4
ETA-IPHO 182	23.2^{a}	4.2^{ab}	.48^{ab}	18.6^{b}	11.3	2.9
Zelder 75—103	23.8^{a}	3.9^{a}	.49^{ab}	16.4^{ab}	12.6	6.1
Avg.	34.0	5.7	.63	16.8	11.2	4.8
LSD .05	8.4	1.6	.17	2.5		

The fresh yields, dry matter yields and protein yields in 1977 equalled the ones obtained in 1976, although the growing conditions were even poorer than those in 1976 (Table 5). In 1978 (Table 6) the average yield of 23 varieties was 43.3 (35.4—50.9) tons/ha fresh yield, 6.6 (4.9—8.0) tons/ha DM yield and 430 (340—500) kg/ha protein yield. The yields of silage maize on 1976—78 equal those obtained by ANDERSSON and LÖÖF (1959) in Sweden.

Quality of the yield

The percentage of ears of the total dry matter yield is a good indicator of the growing factors available to maize in any growing season. In a very favorable years in 1975 the percentage of ears of all varieties was 49.1 %, in 1978 18.1 % and in the very unfavorable years 1976—77 only 4.0—5.7 %. The same trend, although not so clear, can be found in the dry matter content of the yield. The season 1975 represents a level of 23.3 % and the years 1976—78 a level of 15.1—16.8 % (Tables 3, 4, 5, 6). The protein content of all varieties over all years is between 4.7 % and 12.7 %. The figures equal those obtained in Sweden (NORDFELT 1959).

Varieties

The varieties common to yield trials of the years 1976—78 were *LG 5*, *LG 7*, *LG 9*, *LG 11*, *CP 170*, *Rubis 9*, *Flash* and *AGG 200* from France, *Edo*

Table 5. Fresh weight, dry matter (DM) and protein yields and DM, protein and ear content (%) of silage corn varieties in southern Finland in 1977.

Variety	Yields tons/ha			Content %		
	Fresh wt	DM	Prot.	DM	Prot.	Ears
CP 170	45.2^{c}	6.90^{c}	.72^{b}	15.3^{ab}	10.5	4.1
Prior	46.3^{c}	6.79^{c}	.75^{b}	14.6^{ab}	11.0	3.4
LG 9	40.2^{bc}	6.21^{bc}	.65^{b}	15.5^{ab}	10.4	2.0
LG 7	40.7^{bc}	6.13^{bc}	.61^{b}	15.1^{ab}	10.0	5.1
Rubis 9	36.2^{b}	6.11^{bc}	.66^{b}	16.9^{bc}	10.8	7.1
Blizzard	41.5^{bc}	5.94^{bc}	.69^{b}	14.2^{a}	11.5	5.5
ACG 200	41.7^{bc}	5.94^{bc}	.65^{b}	14.2^{a}	11.0	4.8
Flash	37.2^{b}	5.84^{bc}	.58^{b}	15.7^{ab}	10.0	6.4
LG 11	39.6^{bc}	5.82^{bc}	.59^{b}	14.9^{ab}	10.2	3.2
Velox	38.9^{bc}	5.72^{bc}	.64^{b}	14.7^{ab}	11.2	6.1
LG 5	37.8^{bc}	5.68^{bc}	.61^{b}	15.1^{ab}	10.7	5.0
HIT	36.0^{b}	5.39^{b}	.61^{b}	15.0^{ab}	11.5	6.4
Hansa	28.7^{ab}	5.04^{ab}	.54^{ab}	17.5^{c}	10.8	5.7
EDO	30.9^{ab}	5.01^{ab}	.52^{ab}	16.1^{bc}	10.4	8.9
Nibak	30.1^{ab}	4.81^{ab}	.55^{ab}	16.0^{b}	11.5	8.6
Kentala	31.4^{ab}	4.60^{ab}	.58^{ab}	14.7^{ab}	12.7	9.5
ACG 188	28.4^{a}	4.35^{ab}	.51^{ab}	15.1^{ab}	11.6	3.6
ML 06	27.7^{a}	4.03^{a}	.46^{a}	14.5^{a}	11.4	8.3
ETA-Ipho 182	25.5^{a}	4.00^{a}	.45^{a}	15.1^{ab}	11.3	4.6
Jacques Cartieur	26.4^{a}	3.77^{a}	.44^{a}	14.4^{a}	11.6	5.3
Avg.	35.5	5.40	.59	15.2	11.0	5.7
LSD .05	7.4	1.3	.14	1.4		

Table 6. Fresh weight, dry mater (DM) and protein yields and DM, protein and ear content (%) of silage corn varieties in southern Finland in 1978.

Variety	Yields tons/ha			Content %		
	Fresh wt	DM	Prot.	DM	Prot.	Ears
ACG 201	50.9^{ab}	8.04^{c}	$.38^{ab}$	15.8^{bc}	4.7	12.9
Forla	47.4^{ab}	7.78^{bc}	$.49^{bc}$	16.4^{c}	6.3	25.0
LG 11	47.2^{ab}	7.51^{bc}	$.50^{bc}$	15.9^{bc}	6.7	8.4
CP 170	48.5^{ab}	7.28^{bc}	$.47^{bc}$	15.0^{b}	6.4	16.4
ACG 185	47.6^{ab}	7.28^{bc}	$.48^{bc}$	15.6^{bc}	6.6	16.2
LG 9	46.9^{ab}	7.15^{bc}	$.47^{bc}$	15.3^{bc}	6.5	10.3
Rubis 9	43.5^{ab}	6.86^{bc}	$.38^{ab}$	15.7^{bc}	5.6	19.3
ACG 189	45.8^{ab}	6.77^{bc}	$.47^{bc}$	14.8^{b}	6.9	19.3
ACG 167	45.8^{ab}	6.69^{bc}	$.54^{c}$	14.6^{ab}	8.1	19.9
Hansa	41.7^{ab}	6.65^{bc}	$.35^{ab}$	16.8^{cd}	5.3	23.1
Blizzard	40.6^{ab}	6.58^{b}	$.38^{ab}$	14.6^{ab}	6.6	16.0
HIT	41.0^{ab}	6.51^{b}	$.40^{ab}$	15.9^{bc}	6.2	26.4
LG 5	43.1^{ab}	6.50^{b}	$.48^{bc}$	15.1^{b}	7.4	13.9
ML 06	41.2^{ab}	6.22^{ab}	$.44^{b}$	15.1^{b}	7.0	23.5
EDO	39.8^{ab}	6.20^{ab}	$.39^{ab}$	15.6^{bc}	6.3	28.6
ACG 170	45.8^{ab}	6.20^{ab}	$.48^{bc}$	13.6^{a}	7.8	10.8
Joran	39.4^{ab}	6.14^{ab}	$.49^{bc}$	15.6^{b}	8.0	16.6
Silac 233	42.7^{ab}	6.01^{ab}	$.41^{ab}$	14.0^{ab}	6.8	10.1
Prior	42.7^{ab}	6.00^{ab}	$.37^{ab}$	14.1^{ab}	6.1	16.9
Flash	38.7^{ab}	5.96^{ab}	$.36^{ab}$	15.4^{bc}	6.0	16.9
Mutin	39.9^{ab}	5.86^{ab}	$.44^{b}$	14.7^{ab}	6.2	16.4
LG 7	41.4^{ab}	5.81^{ab}	$.44^{b}$	14.0^{ab}	7.6	14.0
ACG 200	35.4^{a}	4.91^{a}	$.34^{a}$	13.9^{ab}	7.0	19.6
Avg.	43.3	6.56	.43	15.1	6.6	17.5
LSD .05	14.7	1.45	.09	1.1		

Hit and *Hansa* from Germany and *Prior*, a Dutch variety. The yield level of these varied between 33.8—43.7 tons/ha (Table 7). This yield level is the same as reported by VIRTANEN (1938) in private farming in the thirties. However, the varieties were less developed but the weather conditions much more favorable at that time.

In 1976—78 the average dry matter yield of 12 varieties was 6.2 tons/ha. The nine best varieties did not differ statistically from each other. The yield level of 1976—78 was 3.6 tons DM/ha lower than the yield level of seven varieties in 1975 revealing differences in growth conditions between the years. The average protein yield of 580 kg/ha apparently very well represents the average protein producing ability of silage maize under Finnish growing conditions. The dry matter content of all varieties (15.8 %) as well as the contribution of ears to the total DM (9.3 %) reveals the very low level of maturity.

All varieties ceased apical growth by the end of August. The average height of all varieties was 218 cm. The protein content of the ear yield was higher than that of the stem (Table 8). As the dry mater yield of the ears was quite poor, the protein content of the ears plays an unimportant role in the total protein yield, especially in unfavorable seasons.

Table 7. Average fresh, dry matter and protein yields tons/ha and percentage of DM, protein and ears in the total dry matter yield of twelve corn varieties studied in 1976—78 in Suitia.

Variety	Yields tons/ha			DM	Prot.	Ears	Height
	Fresh	DM	Prot.	%	%	%	cm
LG 11	43.7^{b}	6.93^{b}	.64^{b}	15.8^{b}	9.3^{ab}	5.2^{a}	218^{b}
CP 170	42.3^{b}	6.72^{b}	.62^{b}	16.1^{b}	9.4^{ab}	7.9^{a}	226^{b}
LG 9	41.8^{b}	6.66^{b}	.60^{ab}	16.1^{b}	9.4^{ab}	5.1^{a}	228^{b}
Rubis 9	38.5^{ab}	6.40^{ab}	.56^{ab}	16.7^{c}	8.9^{a}	10.0^{b}	220^{b}
Prior	43.1^{b}	6.30^{ab}	.58^{ab}	14.6^{a}	9.5^{ab}	7.5^{a}	222^{b}
HIT	39.1^{ab}	6.26^{ab}	.60^{ab}	16.0^{b}	9.5^{ab}	13.3^{bc}	216^{ab}
Hansa	36.5^{a}	6.12^{ab}	.55^{ab}	17.1^{c}	9.1^{ab}	12.5^{bc}	223^{b}
LG 7	40.1^{b}	6.07^{ab}	.58^{ab}	15.1^{ab}	9.4^{ab}	8.6^{ab}	216^{ab}
LG 5	38.2^{ab}	6.00^{ab}	.58^{ab}	15.8^{b}	9.8^{b}	7.1^{a}	218^{b}
Flash	36.7^{a}	5.80^{a}	.52^{a}	15.8^{b}	9.0^{ab}	9.7^{ab}	214^{a}
EDO	33.8^{a}	5.54^{a}	.52^{a}	16.4^{bc}	9.5^{ab}	15.4^{c}	205^{a}
ACG 200	38.0^{ab}	5.54^{a}	.55^{ab}	14.6^{a}	9.8^{b}	9.2^{ab}	214^{a}
Avg.	39.3	6.20	.58	15.8	9.4	9.3	218
LSD .05	6.0	.93	.09	.9	.9	4.8	12

Table 8. Dry matter yields, dry matter and protein content of twelve corn varieties studied from stens and ears in 1976—78 in southern Finland.

Variety	Stems			Ears		
	DM tons/ha	DM %	Prot. %	DM kg/ha	DM %	Prot. %
LG 11	6.48^{b}	18.0^{b}	7.9^{ab}	360^{a}	7.1^{a}	18.0^{b}
CP 170	6.10^{ab}	17.4^{b}	8.2^{ab}	548^{a}	7.5^{a}	16.2^{b}
LG 9	6.11^{ab}	16.7^{ab}	8.7^{b}	316^{a}	7.5a	17.8^{b}
Rubis	5.84^{ab}	18.0^{b}	7.0^{a}	637^{ab}	8.5^{ab}	16.4^{b}
Prior	5.90^{ab}	15.6^{a}	8.8^{b}	462^{a}	7.7^{a}	18.7^{b}
HIT	5.74^{ab}	17.6^{b}	7.6^{ab}	938^{b}	10.5^{b}	13.8^{a}
Hansa	5.13^{ab}	18.0^{b}	7.8^{ab}	693^{ab}	11.1^{b}	13.8^{a}
LG 7	6.11^{ab}	16.6^{ab}	8.1^{ab}	574^{ab}	8.8^{ab}	15.2^{ab}
LG 5	5.84^{ab}	16.8^{ab}	8.0^{ab}	444^{a}	8.5^{ab}	16.8^{b}
Flash	5.53^{ab}	16.9^{ab}	7.9^{ab}	625^{ab}	10.4^{b}	14.2^{a}
EDO	5.06^{a}	18.0^{b}	8.7^{b}	987^{b}	10.3^{b}	15.5^{ab}
ACG 200	5.79^{ab}	17.1^{ab}	7.9^{ab}	532^{a}	8.6^{ab}	16.7^{b}
Avg.	5.80	17.2	8.1	593	8.9	16.1
LSD .05	1.36	1.6	1.5	384	2.0	1.8

Temperature requirements in the developmental phases of maize

The average time for emergence of all varieties in 1976—78 was 15 days (Table 9). No differences could be found between the emergence times of the varieties. The temperature requirements for emergence, tasseling and silking were counted in three different ways (Table 9). Corn heat units (CHU) appeared to be the most precise measure for emergence. The average day temperature during germination was 11° C, which is 1.8° C lower than that

Table 9. Average number of days, degree days (DD), effective degree days (EDD) and corn heat units (CHU) of all corn varieties, studied in 1976—78 in southern Finland.

		1976	1977	1978	Avg.
Emergence	Days from seeding	12	21	11	15
	°C DD	139	195	149	161
	°C EDD	30	15	39	28
	°C CHU	135	144	143	141
Tasseling	Days from seeding	93	90	77	89
	°C DD	1 256	1 213	1 119	1 196
	°C EDD	340	347	348	346
	°C CHU	1 268	1 203	1 133	1 201
Silking	Days from seeding	105	100	86	97
	°C DD	1 411	1 350	1 240	1 334
	°C EDD	378	383	386	382
	°C CHU	1 436	1 344	1 273	1 351

recommended for seeding day temperatures in Canada (Brown 1975). In several tests in Sweden the average time from seeding to emergence has been 14 days, which conforms with the results obtained in Finland (Åkerberg and Torssell 1959).

The average growing time from seeding to tasseling during three test years was 89 days. In 1976 the range of all varieties was 85—99 days, the fastest being the variety *Velox* and the slowest *Ipho 182*. In 1977 the range was 90—104 days and the extremes were *Velox* and *LG 9;* in 1978 the range was 71—82 days and the extremes were *BC 323* and *Silac 233*. The results agree with Shawn's (1955) findings, according to which the time requirement for tasseling is 60 days if the daily average temperature is 21° C throughout the period. The effective degree days (EDD) appear to be the most precise means of determining the temperature requirements from seeding to tasseling in 1976—78. The range in EDD during the three years was only 340—348° C.

Silking of all varieties started on the average 9—12 days after tasseling. The range between the varieties in 1976 was 100—107 days, in 1977 96—111 days, and in 1978 80—90 days. Again EDD seems to be the most precise way of temperature measurement (Table 9).

In variety tests stand height was measured once a week to study the developmental rhythm of silage maize. Plant height and temperature relations were tested with multiple regression. CHU appears to be the best indicator of plant height development of maize. The other characteristics increased the determination coefficient in the order DD, growing days and EDD. The direct correlation between plant height and temperature was as follows:

Height cm — CHU (r = .975***
» — EDD (r = .970***
» — DD (r = .967***
» — Days (r = .962***

Maize plant height development showed a very distinct sigmoid type growth curve as indicated in Figure 1. The plant height levels represent equal temperature levels in three different heat unit systems. In Figure 2 the dry matter yields of maize are presented in the same way.

Limitations of maize growth and development in Finland

Maize growth during the Finnish summer is determined by the frost free period and the average temperature of the season. For the Corn Belt area in the USA the ideal season is as follows (Wallace and Bressman 1937):

May:	mean temperature 18 °C 85 mm of rain
June:	mean temperature 21.5° C 85 mm of rain
July	mean temperature 22.8° C 115 mm of rain
August:	mean temperature 22.8° C 115 mm of rain
Sept.:	warmer and drier than average

Table 10 gives the occurrences of minimum autumn temperatures of 0 and −2° C in four locations in southern Finland. The line connecting these four locations is roughly the northern limit for tentative maize production in this country. The killing frost −2° C usually falls between September 28 and October 16. The 95 % confidence limits of the first fatal frost are between September 16 and October 16. Thus the frost free growing season for maize will roughly be from June 1 to September 16.

Table 11 gives the distribution of the growing seasons of 16 years into DD-classes at the same four locations. The best early varieties available at present produce a mature grain crop at DD-sums of about 2 000 with no interfering late spring or early autumn frosts. This means that one can expect to harvest a mature grain yield twice in ten years.

If the condition for late milk stage silage yield is DD 1900 and the first fatal frost in the later part of September, one may expect a reasonable crop of this kind some six times in ten years in Finland.

Table 10. The occurrence of ±0 °C and −2 °C frost in the autumn and 95 % confidence limits, average 1963—78, four locations in southern Finland.

Frost limits	Turku	Jokioinen	Tikkurila	Lappeenranta
0° C avg.	22/9	11/9	17/9	27/9
≥P.95 %≤	16/9—28/9	1/9—21/9	9/9—25/9	22/9— 2/10
V %	71.2	65.8	117.7	51.7
−2° C avg.	6/10	30/9	28/9	6/10
≥P.95 %≤	27/9—16/10	22/9— 9/10	16/9—10/10	30/9—13/10
V %	62.1	78.5	137.8	62.5

A satisfactory silage crop can be reached at DD 1800 with no fatal frost earlier than Sept. 20. Along the Finnish coastline (and on the Åland islands) one can expect such conditions eight times in ten years. Although we have

Table 11. The distribution of growing seasons of years 1963—1978 according to the degree days into six temperature classes in four locations of southern Finland and the average degree days between May 11 — Sept. 27 of sixteen years.

Degree Days °C	Number of years Turku	Jokioinen	Tikkurila	Lappeenranta
>2101	1	—	2	2
2001—2100	3	2	3	2
1901—2000	7	2	5	3
1801—1900	4	7	5	6
1701—1800	1	4	1	3
1601—1700	—	1	—	—
Avg. °C	1942	1845	1952	1920

no particular experience of growing maize on the Åland islands it would seem that some areas, where sugarbeets are now grown particularly well, should also be well suited for maize.

Summarizing from Tables 1, 10 and 11 one may conclude that maize production in such extremely northerly areas as southern Finland is limited basically due to the occurrence of fatal low temperatures during the vegetative period, which otherwise would be long enough under normal years. This temperature deficit is particularly hazardous at the beginning of the growing season. In particular, resistance to occasional low temperatures should thus, be emphasized in maize breeding programs for extremely northern locations.

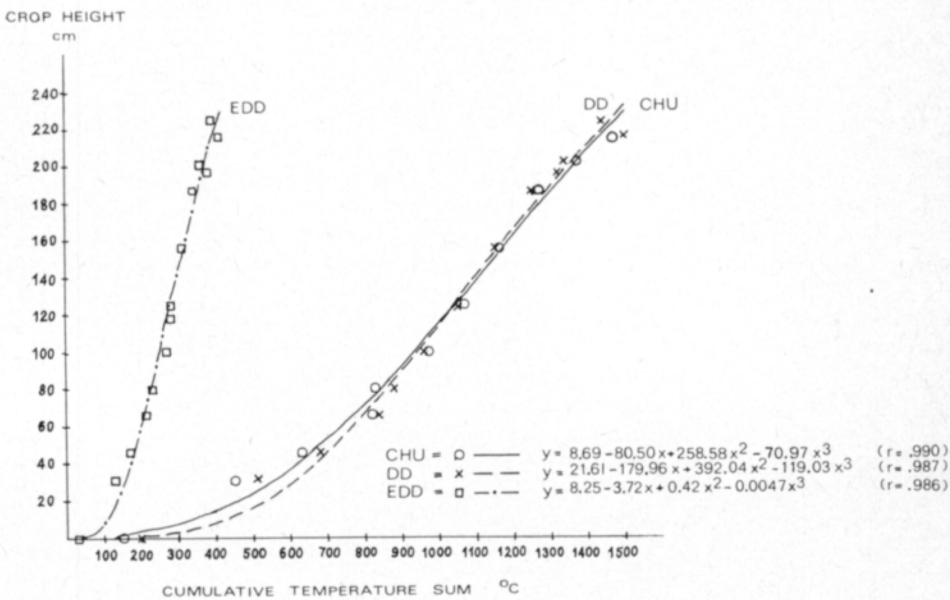

Fig. 1. The relationship between the crop height and cumulative temperature sum °C during the growing season expressed in degree days (DD), in effective degree days (EDD) and in corn heat units (CHU) in variety tests in 1976—78.

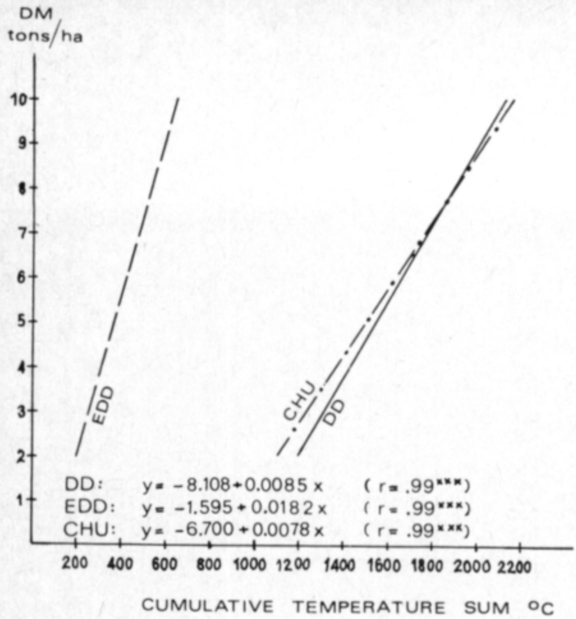

Fig. 2. The relationship between the dry matter production of maize and the cumulative temperature sum °C expressed in degree days (DD), in effective degree days (EDD) and in corn heat units (CHU).

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SELOSTUS

Maissilajikkeiden sopeutumisesta Suomen kasvuoloihin

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Maissin lajikekokeet Suomen Kulttuurirahaston tuella käynnistettiin Wiurilassa, Salossa vuonna 1975. Vuoden 1975 alustavissa kokeissa oli 280 lajiketta. Näistä 19—23 valittiin lopullisiin lajikekokeisiin Yliopiston koetilalle Siuntioon vuosiksi 1976—78. Sääolosuhteet vuonna 1975 olivat keskimääräistä paremmat, vuosina 1976—78 keskimääräistä huomattavasti heikommat.

Kuiva-ainesadot 1975 olivat 5.8—11.5 tn/ha. Vuosina 1976—78 vaihtelut kuiva-ainesadoissa heikoimman ja parhaimman lajikkeen välillä olivat 3.8—8.0 tn/ha. Suotuisana kasvukautena 1975 kovan, kypsän siemenen tuotti 44 lajiketta. Vuonna 1976—77 kypsää siementä ei tuottanut yksikään lajike, vuonna 1978 yksi lajike. Säilörehuasteisen, kellertävän tai keltaisen siemenen tuotti vuonna 1977 kahdeksan lajiketta, vuonna 1978 yhdeksän lajiketta ja vuonna 1976 ei yhtään lajiketta.

Lajikekokeissa löydettiin muutamia lupaavia hybridejä Ranskasta, Saksasta ja Jugoslaviasta. Pitkäaikaisiin lämpötilatietoihin perustuen voidaan todeta, että aikaisista hybrideistä saadaan nykyisillä lajikkeilla kasvuoloissamme kypsä jyväsato kahdesti kymmenessä vuodessa, hyvä säilörehusato kuudesti kymmenessä vuodessa ja tyydyttävä säilörehusato kahdeksan kertaa kymmenessä vuodessa.

Maissin kasvun ja kehityksen tärkein rajoittava tekijä kasvuoloissamme on alhainen vuorokautinen lämpötila koko kasvukaudella. Alhaisesta keskilämpötilasta johtuen lämpötilasumma jää useasti alle 1900° C, jota on pidettävä kannattavan säilörehumaissin viljelyn alarajana. Toinen merkittävä tekijä on ensimmäisen tappavan syyshallan ajoittuminen useasti syyskuun alkupuolelle, mikä oleellisesti vähentää maissin kasvuaikaa. Kevään ja alkukesän usein alhaiset lämpötilat hidastavat maissin alkukehitystä. Tästä syystä maissilla nopean kasvun vaihe saavutetaan vasta elokuun vaihteessa, jolloin lämpöoloissa, ja varsinkin säteilymäärissä on tapahtunut merkittävä vähentyminen.