Theoretical and Applied Genetics 40, 351—356 (1970)

Genetic Factors Affecting Maize Tolerance to Low Temperatures at Emergence and Germination

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Summary. On the basis of the percentage of plants emerging under laboratory cold-test conditions, inbred lines were divided into tolerant (*T*), semi-tolerant (*I*) and sensitive (*S*) to low temperatures. Tolerance to low temperature is, then, an inheritable and varietal plant characteristic.

On average, local varieties showed the best emergence, followed by double crosses, single crosses and inbred lines in that order. Some tolerant hybrids and inbred lines had quite high emergence after 27 days at 6 °C. Thus the tolerant inbred lines *Bc*-130 *E*-5 and *T*-193/II had more emerged seeds (78 and 75% with embryo roots and 52 and 47% with stalk apices, respectively) with longer embryo roots and stalk apices than the sensitive inbred lines *T*-145/II and *W*-8 at the end of this treatment.

The two-year average emergence of 56 reciprocal single crosses and their parental inbred lines cold-tested at 6 °C and 8 °C indicates that the degree of tolerance to low temperatures is strongly dependent on the germination ability of the maternal parent of the cross, i. e. on maternal effect. The genetic mechanism of this inheritance is rather complex. The higher stand density of single crosses over inbred lines may be explained by complementary gene action in the seed embryo. The characteristics of the maternal parent were important in determining not only the percentage of germinated plants, but also the speed of germination and growth of the embryo root and stalk apex. With each parental inbred line the percentage emergence differed according to whether the line was used as the maternal or pollen parent in the crosses.

Introduction

Over the last two decades, plant breeding has dealt extensively with the problem of improving tolerance to low spring temperatures with the aim of producing maize genotypes (inbred lines and hybrids) with better germination, more vigorous emergence and faster early growth under adverse conditions of cold, wet weather. The main problem is to produce good stands under these conditions. Tolerance to low temperatures, according to Levit (1956), is the capacity of a living organism to remain warm during cold conditions. It is the ability of the plant organism to survive natural cooling by the weather.

Breeding maize for better tolerance to low temperatures was first begun in Wisconsin (Neal, 1949) by Leith in 1914 using the variety Holden Glow, which, with emergence at 7.2 °C and after many years of selection, was brought to good cold tolerance and put into extensive production in 1922. Results of breeding work and investigations of the cold tolerance of different maize genotypes at germination and emergence have been reported by Neal (1949), Pinnell (1949), Rinke (1963), Åberg and Åkerberg (1958), Polarecky (1965), Sokolov and Ivahnenko (1963), Sokolov (1968), Kozubenko (1963), Brown (1967), Pešev (1969, 1969a), Koch and Müller (1963).

More recently, quite a lot of attention has been given to investigating the genetics of maize tolerance to low temperatures at germination, emergence and during early plant growth (Tatum, 1954; Pinnell, 1949; Wartman, 1950; Ventura, 1961; Pešev, 1969; Sokolov and Ivahnenko, 1963; and Helgason, 1953).

Low temperatures (8—12 °C) following planting retard the physiological activities of germinating maize seeds, predisposing them to attack by various soil organisms (Neal, 1949; Pinnell, 1949). Several groups of factors are known to influence the stand when it grows during low temperatures; they include genetic constitution of the strain (Helgason, 1953; Wartman, 1950), the amount and type of seed coat injury, seed age and seed maturity, as well as the occurrence of frost before the seed is harvested (Rush and Neal, 1951).

In Yugoslavia and some other countries of Middle and Southeastern Europe, the problem of maize tolerance to cold at the germination stage arises with early sowings in lowland regions and with normal sowings in highland regions. In Canada and some countries of Central and Northern Europe, where maize is now being introduced or extended, tolerance to low temperatures at germination is a very important factor (Åberg and Åkerberg, 1958; Koch and Müller, 1963; Sokolov, 1968; and Brown, 1967).

The study of hybrids whose parental components differ strongly in some property offers a good prospect of obtaining reliable data. This is especially important in genetic studies of the inheritance of crucial characteristics such as the tolerance to low temperature at germination and emergence of the F_1 of reciprocal single crosses and their parental lines — the principal aim of the present paper.

Material and Methods

The experiments were carried out at the Agricultural Experiment Station at Zaječar in 1958—1960 and at the Maize Research Institute, Belgrade-Zemun in 1960—1961.

From 1958 to 1960, cold tolerance at emergence was tested under laboratory conditions at 6 and 8 °C. There were 23 domestic and foreign inbred lines, 4 American single crosses, 3 double crosses (Wisconsin 641 A, Nebraska 301 and Ohio *C*-92) and 14 native Yugoslav varieties. In 1960 and 1961, 56 reciprocal single crosses and their 8 parental inbred lines with varying tolerance were cold-tested at 6 °C and 8 °C in the laboratory. All materials were also tested in early sowings, March 18, 1958, March 6, 1959 and March 25, 1960.

The germination ability of the material was tested by sowing 25 kernels, in 4 replications, according to a modification of the method of Pinnell (1949) and Helgason (1953): 2 days at 22—24 °C, 10 days in a refrigerator at 8 °C, after which the pots were exposed to room temperatures until germination was complete. The stands were counted, measured and rated for vigour after germination. The soil was taken from a plot where maize had been cultivated for 2—3 years. Tin pots 20 × 20 cm and 6 cm deep were used (Rush and Neal, 1951) and soil moisture was kept at 60% of maximum water capacity (Helgason, 1953). Four lines or hybrids were sown in each pot. In 1959 and 1960 all the inbred lines were tested at 6 °C for 27 days, and in 1960 and 1961 all the reciprocal single crosses. The seed used had been harvested at maturity, dried in the laboratory, husked by hand, and treated with tiralin. Sowing was done according to a random block design.

Fisher's analysis of variance was applied to the results, the numerical values being converted into comparative percentages ($p = \sin^2 \Theta$) using Bliss' tables (Hayes et al., 1955).

Table 1. *Emergence of inbred lines (%) after cold-testing in a refrigerator in 1958, 1959 and 1960*

No.	Inbred line	% emerged plants by year and on average							
		1958	1959		1960		Two year av.	Three year av.	Average for all tests
		8 °C	6 °C	8 °C	6 °C	8 °C	6 °C	8 °C	
1	*Wf*-9	28.0	35.0	56.0	36.0	49.0	35.5	44.3	40.8
2	*N*-6	50.0	52.0	71.0	50.0	69.0	51.0	63.3	58.4
3	*M*-14	47.0	51.0	66.0	48.0	58.0	49.5	57.0	54.0
4	*W*-32	46.0	45.0	62.0	46.0	57.0	45.5	55.0	51.2
5	*W*-187	21.0	29.0	53.0	26.0	48.0	27.5	40.7	35.4
6	*A*-374	36.0	39.0	57.0	35.0	49.0	37.0	47.3	43.2
7	*A*-375	39.0	33.0	48.0	28.0	37.0	30.5	41.3	37.0
8	*W*-8	32.0	36.0	56.0	29.0	36.0	32.5	41.3	37.8
9	*W*-20	51.0	50.0	69.0	46.0	62.0	48.0	60.6	55.6
10	*W*-68A	54.0	49.0	66.0	46.0	63.0	47.5	61.0	55.6
11	*Hy*	38.0	37.0	56.0	40.0	58.0	38.5	53.3	45.0
12	*T*-536/III	52.0	49.0	64.0	43.0	54.0	46.0	56.6	52.4
13	*T*-193/II	69.0	55.0	74.0	54.0	70.0	54.5	71.0	64.4
14	*T*-226	37.0	37.0	49.0	28.0	39.0	32.5	41.7	38.0
15	*T*-145/II	32.0	27.0	44.0	27.0	39.0	27.0	38.0	33.8
16	*T*-314	29.0	38.0	50.0	36.0	44.0	37.0	41.0	39.4
17	*V*-312	42.0	44.0	59.0	42.0	58.0	43.0	53.0	49.0
18	*R*-581	22.0	34.0	46.0	32.0	43.0	33.0	37.0	35.4
19	130 *E*-5	68.0	57.0	75.0	58.0	71.0	57.5	71.6	66.0
20	*ZF*-79	63.0	54.0	69.0	53.0	66.0	53.5	66.0	61.0
21	*ZF*-60	42.0	44.0	62.0	39.0	54.0	41.5	52.6	48,2
22	*ZF*-51/1—2	39.0	39.0	56.0	43.0	54.0	41.0	49.7	46.2
23	*T*-6/1	57.0	46.0	52.0	51.0	63.0	48.5	57.3	53.8
Average		43.4	42.6	59.2	40.6	54.0	41.9	52.2	47.9
LSD at 5%		8.6	7.6	7.4	9.1	8.3	—	—	—

Results and Discussion

Cold Tests and Emergence of Inbred Lines, Hybrids and Domestic Varieties

The three-year average emergence of the inbred lines after cold-testing for 10 days at 8 °C was 52.2% (Tab. 1) and the two-year average after 27 days at 6 °C was 41.9%.

Using the three-year average emergence in the early sowing field trials, Pešev (1969a) divided inbred lines into tolerant, with more than 58% of plants emerging, semi-tolerant with 48—58%, and sensitive to low temperatures, with less than 48% emerging. Pinnell (1949) classified as tolerant lines with more than 52% plants emerged after early sowing.

The inbred lines tested may be grouped as follows, on the basis of percentage emergence from early sowing (Pešev, 1969a) and under laboratory cold-test conditions at 6 °C and 8 °C (Tab. 1):

a) tolerant: *Bc*-130 E-5, *T*-193/II, *ZF*-79, *N*-6, *M*-14, *W*-20, *W*-68*A* and *W*-32;
b) sensitive: *W*-8, T-226, *T*-145/II, *R*-581, *A*-374, *A*-375, *Wf*-9, *ZF*-51 and *T*-314;
c) semi-tolerant: *V*-312, *Hy*, *T*-6/1, *T*-536/III and *ZF*-60.

After 27 days at 6 °C the tolerant lines *Bc*-130 *E*-5 and *T*-193/II had more emerged seeds (78 and 75% respectively with an embryo root, and 52 and 47% with a stalk apex) and longer embryo roots and stalk apices than the sensitive lines. Thus, tolerant lines were able to emerge at 6 °C, while sensitive lines had no plants with developed stalk apices after 27 days at that temperature (Tab. 2).

The inbred lines were —2 to +2 LSD from the average in the laboratory tests (Tab. 3) but —4 to +4 LSD in the field trials. This indicates that with longlasting and variable low soil temperatures the field trials were more discriminating than the laboratory tests.

The three-year average emergence of single crosses after cold-testing at 8 °C was 59.3%, of double crosses 66.3% and domestic varieties 77.6% (Tab. 4). The tolerance ratings of maize genotypes for ability to germinate and emerge under low temperature conditions were the same in the laboratory tests and in the field trials. Consequently, laboratory tests of the cold

Table 2. *Growth of embryo roots and stalk apices of inbred lines after cold testing for 27 days at 6 °C in 1959*

Inbred line	% plants with		Av. length on removal from refrigerator (cm)		Emerged plants (%) at	
	embryo root	stalk apex	embryo root	stalk apex	6 °C	8 °C
ZF-60	42.0	28.0	0.8	0.5	44.0	62.0
Bc-130 *E*-5	78.0	52.0	2.0	0.6	57.0	76.0
T-226	36.0	5.0	0.3	0.2	37.0	49.0
Wf-9	25.0	0.0	0.4	0.2	36.0	56.0
M-14	60.0	10.0	0.5	0.2	51.0	66.0
T-536/III	78.0	40.0	0.5	0.5	49.0	64.0
V-312	31.0	16.0	0.4	0.3	44.0	59.0
T-193/II	75.0	47.0	1.9	0.7	55.0	74.0
W-68 A	62.0	35.0	0.4	0.2	49.0	66.0
T-145/II	26.0	0.0	0.2	0.2	27.0	44.0

Table 3. *Grouping of inbred lines according to the percentage of emerged plants at 6 °C and 8 °C in the laboratory and early field trials*

Treatment	Classes from −4 to +4 times *LSD* at 5%									Av. emerged plants (%)
	−4−3−2−0				+1+2+3+4					
Three-year av. with cold-testing at 8 °C	—	—	2	7	5	6	3	—	—	52.2
Two-year av. with cold-testing at 6 °C	—	—	2	7	4	8	2	—	—	41.9
Three-year av. with early field sowing	1	2	1	4	4	4	3	3	1	48.3

tolerance of different genotypes at the germination and emergence stages can give reliable results.

Pinnell (1949) found a strong positive correlation ($r = 0.75$) between tolerance of inbred lines tested under early sowing conditions and under laboratory conditions.

Table 4. *Three-year average emergence of inbred lines, hybrids and local varieties*

Treatment	Emergence of plants (%)			
	Inbred lines	Single crosses	Double crosses	Domestic varieties
Early field sowing	48.3	57.1	61.8	70.8
Cold-testing at 8 °C	52.2	59.4	66.3	77.6

Reciprocal Single Crosses and Their Parental Inbred Lines

The 8 inbred lines used for the test crossings were similarly divided into tolerant (*T*), semi-tolerant (*I*) and sensitive (*S*) to low temperatures according to emergence percentage in the laboratory and field tests (Tab. 5). This means that this tolerance is a heritable and varietal characteristic of maize.

There were significant differences in emergence between the parental inbred lines after cold-testing at 6 and 8 °C (Tab. 6 and 7). The tolerance rankings of these lines for stand density in the 8 °C cold test (Tab. 7) are the same as their distribution in table 5. Their rankings for emergence in the 6 °C cold test were also the same, except for insignificant differences in the rankings of 130E-5 and T-226.

It is interesting to compare the most (max.) and least (min.) dense stands, after treatment at 6 and 8 °C of single crosses in which the most tolerant (*Bc*-130*E*-5) and most sensitive (*T*-226) lines served as the maternal parent. With *Bc*-130*E*-5, the maximum stands were obtained by crossing with *T*-193/II ($T \times T$) — 66.9% at 6 °C and 77.8% at 8 °C. These were also the densest stands obtained from all test crossings. This same line gave its minimal stand when crossed with *T*-226-52.4 and 75.6% respectively. When used as the maternal parent, the most sensitive line, *T*-226, produced its maximum stand when crossed with *ZF*-60 ($S \times I$) 46.4 and 57,9% respectively, and minimum when crossed with *W*-8 ($S \times S$) — 33.1 and 44% respectively. This was the

Table 5. *Emergence of inbred lines in early sowing in field trials and after cold testing in laboratory at 8 °C and at 6 °C 1958—1960*

Inbred line	Degree of tolerance*	Three year average			Three year av. emergence at 8 °C	Two year av. emergence at 6 °C
		Emergence in the field trials	Temperatures °C until emergence			
			av. daily	sum. of actives		
Bc-130 *E*-5	*T*	63.7	9.7	95.1	71.6	57.5
T-193/II	*T*	64.0	9.7	94.6	71.0	54.5
W-20	*T*	59.2	10.0	105.9	60.6	48.0
W-68*A*	*T*	59.6	9.9	100.6	61.0	47.5
T-536/III	*I*	50.7	9.8	104.5	56.6	46.0
ZF-60—12	*I*	52.4	9.9	103.7	52.6	40.5
W-8	*S*	45.2	10.1	115.1	41.6	32.5
T-226	*S*	40.9	10.1	109.6	41.6	32.5

T = tolerant, *I* = semi-tolerant and *S* = sensitive

Table 6. *Two-year average emergence ($Syn^2\ \Theta$) of single crosses and their parental inbred lines after cold-testing at 6 °C for 27 days in 1960 and 1961* (%)

♀ \ ♂	130 *E*-5	*T*-193/II	*W*-20	*W*-68*A*	*T*-536/III	*ZF*-60	*W*-8	*T*-226	Average	Emergence ratio in reciprocal crossing %
130 *E*-5	**53.6***	66.9	61.6	56.9	57.4	58.1	59.4	52.4	60.4	60.4:48.5
T-193/II	57.4	**54.0**	60.8	62.7	54.0	60.8	56.6	58.9	58.7	58.7:49.7
W-20	50.8	59.3	**48.2**	53.6	42.1	58.6	47.6	54.4	52.2	55.2:50.3
W-68 *A*	49.6	46.7	52.8	**48.5**	43.2	59.6	40.6	56.4	49.5	49.5:49.0
T-536/III	51.7	50.8	52.8	52.6	**45.2**	57.8	49.6	50.1	52.2	52.2:49.1
ZF-60/1 − 2	50.8	45.1	47.8	44.3	43.9	**43.5**	42.1	51.7	46.6	46.6:55.1
W-8	39.4	39.3	39.3	33.0	42.6	45.7	**32.8**	37.6	39.5	39.5:47.0
T-226	40.4	40.1	37.4	40.4	40.5	47.4	33.1	**33.2**	39.9	39.9:53.1
Average ♂	48.5	49.7	50.3	49.0	49.1	55.1	47.0	53.1	50.2	

LSD at 5% = 6,65%

Table 7. *Two-year emergence of single crosses and their parental inbred lines after cold-testing at 8 °C, 1960 and 1961* (%)

♀ \ ♂	130 *E*-5	*T*-193/II	*W*-20	*W*-68A	*T*-536/III	*ZF*-60	*W*-8	*T*-226	Average ♀	Emergence ratio in reciprocal crossing %
130 *E*-5	**64.7***	77.8	77.8	73.6	77.8	70.4	76.7	75.6	75.7	75.7:62.8
T-193/II	73.4	**62.9**	74.5	64.9	73.6	67.2	76.4	71.1	71.5	71.5:60.8
W-20	68.3	64.2	**57.0**	63.4	65.3	69.3	58.2	68.9	65.2	65.2:61.2
W-68*A*	69.4	60.4	52.4	**57.8**	59.4	74.4	61.4	70.8	64.0	64.0:61.2
T-536/III	69.6	66.4	64.5	69.8	**50.2**	64.0	61.8	68.1	66.3	66.3:61.7
ZF-60/1 − 2	54.6	56.5	52.0	53.4	52.2	**50.6**	55.4	56.4	64.5	54.4:65.8
W-8	48.3	43.5	51.9	49.9	50.3	58.3	**42.5**	51.0	50.5	50.5:61.9
T-226	56.2	55.2	55.5	55.3	53.5	57.9	44.0	**41.9**	51.1	51.1:66.0
Average ♂	62.8	60.8	61.2	61.2	61.7	65.8	61.9	66.0	62.3	

LSD at 5% = 7,3%

lowest stand density obtained from any of the 56 test hybrids.

The two-year average emergence ratings of the 56 reciprocal single crosses and their parental inbred lines after treatment at 6 and 8 °C indicate that the degree of tolerance to low temperatures is strongly dependent on the emergence ability of the maternal parent, a phenomenon known as „maternal effect". The higher stand density of the single crosses compared with the inbred lines may be explained by complementary gene action in the seed embryo and as an effect and characteristic of the seed endosperm and pericarp.

The average percentage emergence of single crosses differed according to whether the parental inbred line was used as the maternal or pollen parent (Tab. 6 and 7).

Tatum (1954), Pinnell (1949) and Helgason (1953) have shown that the emergence of single crosses under low temperature conditions is closely correlated to the cold tolerance of their maternal parent. Tatum ascribed this to pericarp influence. According to Pinnell, the nature of the endosperm may be responsible for the portion of inheritance directly related to the maternal parent. Wartman (1950) points out that endosperm effect appears to be important for gene and cytoplasm interaction in the expression of maternal effect on the emergence of maize single crosses in cold-tests.

Crosses between two tolerant inbred lines ($T \times T$) had on average the highest emergence (56.6%) when tested at 6 °C, as did all crosses (Tab. 8) derived from a tolerant maternal parent and a semi-tolerant pollen parent ($T \times I = 56.7\%$) or a sensitive pollen parent ($T \times S = 54.5\%$). On average, crosses between two sensitive lines ($S \times S$) had the lowest emergence (35.5%), the difference between this and the first group above being very significant. Again, these results show the effect of the maternal parent on the emergence of single crosses under low temperature conditions.

Table 8. *Grouping of single crosses, obtained from the lines of different degree of resistance, according to the emergence after testing at 6 °C*

Groups of crossings	Classes from −3 to +3 times *LSD* at 5%							Number of hybrids	Average emergence %
	−3	−2	−1	0	+1	+2	+3		
$T \times T$	—	—	1	4	3	3	1	12	56.6
$T \times I$	—	—	1	1	4	2	—	8	56.7
$T \times S$	—	—	2	1	5	1	—	8	54.5
$I \times T$	—	—	2	6	—	—	—	8	49.5
$I \times I$	—	—	1	—	1	—	—	2	48.3
$S \times T$	1	5	2	—	—	—	—	8	38.6
$S \times S$	1	1	—	—	—	—	—	2	35.5

The effect of the maternal parent is also expressed in the degree and speed of germination, namely the percentage of kernels with a broken pericarp, an embryo root or a stalk apex, and the length of the root and apex at the end of the 27 days cold-testing at 6 °C (Tab. 9). For example, the single cross 130*E*-5 × *T*-193/II ($T \times T$) had 46.2% kernels with an embryo root and 35.5% with a stalk apex, the root and apex being 3.8 and 1.4 cm long respectively. At the same time the single cross *T*-226 × *W*-8 ($S \times S$) had only 10% of kernels with an embryo root and 8% with a stalk apex, 0.3 cm and 0.2 cm long respectively.

Table 9. *Difference between single crosses in growth of embryo root and stalk apex after 27 days at 6 °C 1959*

Single cross *F*-1 gen.	Percentage of kernels with			Av. length on removal from refrigerator (cm)	
	broken pericarp	embryo root	stalk apex	stalk apex	embryo root
Bc-130 *E*-5 × *T*-193/II	78.5	46.2	35.5	1.4	3.8
W-20 × *T*-536/III	90.5	68.2	45.8	1.4	3.2
W-20 × *W*-68A	90.7	71.5	34.3	1.3	3.4
W-8 × *T*-193/II	60.4	55.2	10.0	0.5	2.0
T-226 × *W*-68A	52.0	24.0	11.0	0.4	0.5
T-226 × *W*-8	30.0	10.0	8.0	0.2	0.3

It is evident that maternal effect is also manifest in the rapid growth of the single crosses during long-lasting low temperatures. The hybrids most tolerant to low temperatures during emergence ($T \times T$) can have up to 5 times more kernels with a stalk apex and embryo roots and stalk apices almost 7 and 10 times longer respectively than the most sensitive hybrids ($S \times S$).

This effect of the maternal line on the degree of germination and growth of its single crosses under cold-test conditions may be associated with a double contribution from the female side at fertilization, or with the importance of the quantity and quality of kernel endosperm.

The effect of the genotype, however, is great. Significant differences were found between groups of crosses of inbred lines with varying degrees of tolerance, such as $T \times T$, $T \times I$, $T \times S$, $I \times T$, $I \times I$, $S \times I$ and $S \times S$ (Tab. 8). This indicates that tolerant genotypes should be used as parents, and particularly as the maternal parent, to give tolerant single crosses. It may be seen (Tab. 8) that crosses with tolerant maternal parents and those with sensitive maternal parents lie on opposite sides of the average value.

Zusammenfassung

Nach Prüfung der Widerstandsfähigkeit gegen niedrige Temperaturen konnten die untersuchten Mais-Inzuchtlinien in widerstandsfähige (*T*), mittelwiderstandsfähige (*I*) und nichtwiderstandsfähige (*S*) Linien eingeteilt werden.

Die einheimischen Sorten entwickelten sich im Durchschnitt am besten. Dann folgten Doppelhybriden, Einfachhybriden und Inzuchtlinien in dieser Reihenfolge. Einige widerstandsfähige Hybriden und Inzuchtlinien zeigten nach 27 Tagen bei 6 °C eine beachtliche Entwicklung. Die widerstandsfähigen Inzuchtlinien *Bc*-130 *E*-5 und *T*-193/II hatten eine größere Zahl keimender Körner und Primärwürzelchen und Koleoptilen größerer Länge als die gegen niedrige Temperaturen empfindlichen Sorten *T*-145/II und *W*-8.

Die Beobachtung der durchschnittlichen Entwicklung von 56 reziproken Maishybriden und ihren Erbkomponenten bei einer Temperatur von 6 °C und 8 °C während zweier Jahre ergab, daß die Widerstandsfähigkeit der Hybriden gegen niedrige Temperaturen von der Keimfähigkeit der Mutterlinien abhängt, was als mütterliche Prädetermination bezeichnet werden kann.

Der mütterliche Effekt drückt sich nicht nur in einem Einfluß auf die Entwicklung der Pflanzen aus, sondern auch auf den Prozentsatz an Körnern mit gebrochenem Perikarp sowie auf die Länge der Primärwürzelchen und Koleoptilen nach 27 Tagen bei einer Temperatur von 6 °C.

Das Verhältnis der sich entwickelnden Pflanzen war bei reziproken Kreuzungen der Mutter- und Vaterlinien im Durchschnitt für jede Inzuchtlinie verschieden.

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Received June 2, 1970
Communicated by S. Barbacki

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