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BREEDING TOMATOES FOR THEIR ABILITY TO SET FRUIT AT LOW TEMPERATURES

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Introduction

One important factor which, in tomato, restricts fruit-setting at low temperatures, is the production of sufficient amounts of good quality pollen. The work we have done since 1976 in the quest for varieties which are able to set fruit at low temperatures, has been approached in two ways:

1) study of the ability of a collection of varieties to produce sufficient amounts of good quality pollen;

2) study of the ability of some varieties to set fruit by parthenocarpy when all forms of pollination are absent.

Ability to produce sufficient amounts of good quality pollen

A. Experiments performed

We did two complementary series of experiments:

1) study of a collection of varieties in the glasshouse in the form of unheated spring crops;

2) study of the quality of the pollen from a few varieties subjected to low temperatures for a short period in a temperature-controlled environment.

1. Study of a varietal collection in the form of unheated spring glasshouse crops. Approximately 70 varieties and hybrids were studied in the cold-house in 1976 and 1977, planting having been done between 10th and 12th February. Minimum night temperatures varied between 5 and 10° C for several weeks at the time of flowering. We measured, on several occasions during cultivation, the average quantity of pollen produced per flower, as well as the quality of the pollen after staining with aceto-carmin. We furthermore collected and weighed the fruit produced on 4 inflorescences per plant. These inflorescences were vibrated at regular intervals at the time of flowering.

We were thus able, using the Spearman rank correlation coefficient, to study the correlations between pollen quantity (in mg per flower), quality (percentage of normal grains), and yield per plant following vibration. In determining correlations we used measurement data collected from the pollen on dates when its susceptibility to cold was greatest (measures taken late March — early April):

1) the correlation between pollen quality and quantity per flower is significant at the 0,01 level in both experiments (28 lots in 1976, 20 lots in 1977);

2) the correlation between the quantity of pollen per flower and the yield per plant is significant at the 0,01 level in both experiments (28 lots in 1976, 20 lots in 1977);

3) the correlation between pollen quality and yield per plant is significant at the 0,01 level in the 1976 experiment (28 lots) and significant at the 0,05 level in the 1977 experiment (46 lots).

These results enable us to rank the varieties according to behaviour in the cold-house. In Table 1 we show the results obtained in 1976 from the 28 lots in which pollen quantity and quality were measured.

In order to highlight the best varieties, we set the limit values empirically at: quantity of pollen per flower $\geq 0{,}50$ mg; quality of pollen $> 85\%$ normal grains.

Judging from these criteria, the lots which respond best to conditions in the cold-house, are the following: N° 10, a Bulgarian-bred line; Précoce; Apéca and Apédice, lines springing from a cross with Précoce and bred at Montfavet for their ability to set under extreme growing conditions as well as for their combining ability; Montfavet № 63-4 and Montfavet № 63-5: hybrids bred at Montfavet, Apéca is a parent of the first hybrid and Apédice a parent of the second; Lucy, a Montfavet № 63-5 type hybrid obtained by the French firm Caillard, resistant to the tobacco mosaic virus; Supermarmande: a variety bearing flat ribbed fruit. The Marmande type varieties are widely grown in the Mediterranean basin parts.

In the same way, when limit values were set at: quantity of pollen per flower $< 0{,}10$ mg; quality of pollen $< 65\%$ normal grains. The lots producing the least favourable results were Coldset, Earlinorth, Fireball, Pearl Harbor, Primabel, Swift, Veecrop. Now, several of these varieties are mentioned in the literature as behaving well at low temperatures. Among those varieties which behave moderately well, are to be mentioned Moneymaker, Potentate and Puck.

Graph 1 shows development with time of the quantity and quality of pollen in Apédice and Earlinorth during spring crop growth in 1976. We may point out that average temperatures $\left(\frac{\text{minima}+\text{maxima}}{2}\right)$ ranged roughly between 10 and 15° C up to 25th March. The weather became distinctly warmer at that date, average temperatures generally varying between 15 and 20° C. In varieties which behave well in cold conditions such as Apédice, pollen quality is little affected at the time of the first recordings. Quantity decreases but, as these varieties are good pollen producers, the amount produced is, to all appearances, enough to ensure proper setting. In varieties susceptible to cold, such as Earlinorth, low temperatures have a drastic effect on the quantity of pollen produced which is almost non-existent late March-early April. Recurrence in quantity is very fast, between 4th and 14th April (that is, from 10 to 20 days after 25th March taken as the end of the cold spell). As regards pollen quality, recurrence is even quicker than in quantity, being more or less complete on 7th April (that is 13 days after the end of the cold spell).

2. Study of pollen quality following the action of low temperatures on pollen in a temperature-controlled environment. By revealing a positive correlation in low temperature growing conditions, between pollen quality (assessed in vitro after staining with acetocarmin) and the overall yield of plants following vibration of the inflorescences, our results justify the work undertaken to find an early test-measurement for the quality of pollen subsequent to the action of low temperatures. This test must be quick and reliable, allowing varieties to be rated and it must be such as to ensure that the rating concords well with that of the same varieties grown in the cold-house.

We carried out a few preliminary experiments in the following manner: the plants are grown at normal glasshouse temperatures until the very beginning of the flowering period and then placed in a temperature-controlled growth chamber for a few days, after which they are moved back to normal glasshouse temperatures. Following staining with acetocarmin, the pollen is examined between the second and the eighteenth day after removal from the controlled temperature growth chamber.

According to our tests, alternating low temperatures by night (5 to 7° C) with normal temperatures by day (20° C) for 7 days, does not allow any change in pollen to be detected.

In graph 2 we show results obtained in a test done after 5 days treatment at 7° C night and day (with 12 hours daylight). The measurements taken between the 9th and 12th day following the end of the treatment at low temperatures permit differentiation of the varieties: Apédice shows low susceptibility to cold; Earlinorth is very susceptible to cold; Moneymaker behaves moderately well.

There is close concordance between the results obtained in this test and those observed in spring glasshouse crops. Before this test (5 days at 7° C day and night) can be put to general use in breeding programs, we still have to test several varieties, the cold-house behaviour of which is known, and to ascertain precisely when the pollen observation period should fall after completion of the treatment at low temperatures (probably between the 8th and the 13th day).

B. Outlook

When this pollen quality control test, subsequent to exposure of the plants to low temperatures, has been finally perfected, we will be able to screen a good many varieties and breeding lines, the performance of which will be compared with at least one control, Apédice for example, which shows little susceptibility to the effects of low temperatures.

Choice of sources of resistance to low temperatures in the *Lycopersicon esculentum* species seems to be limited. The varieties mentioned in the literature as behaving well at low temperatures have proved to be very disappointing in our conditions (Coldset, Earlinorth, Fireball). Those which show the most promise are № 10, Précoce and the material bred from Précoce, and lastly Supermarmande. The effect of heterosis on the amount and quality of pollen produced in low temperature conditions may partly account for the good performances of several F_1 hybrids (Table 1; Fig. 1).

In order to achieve improved fruit-setting at low temperatures, we shall have to test a great variety of plant material, introduce wild species and then make the best use of the phenomenon of heterosis.

T a b l e 1. **Quantity and quality of pollen from a collection of varieties grown in the cold-house. Spring 1976**

(Average of 2 measures taken between 30th March and 2nd April)

	Quantity, mg/flower	Quality, % normal grains
Lots producing (quantities>0,50 mg per flower; quality>85% normal grains)		
Apéca	0.64	89
Apédice	0.69	89
Lucy (F_1)	0.53	90
Montfavet № 63-4 (F_1)	0.74	87
Montfavet № 63-5 (F_1)	0.75	89
№ 10	0.80	90
Précoce	0.52	89
Supermarmande	0.99	93
Intermediate lots		
Ace 55 VF	0.21	39
Espalier	0.39	89
Jubolne (F_1)	0.39	82
Luca (F_1)	0.28	86
Moneymaker	0.45	77
Montfavet № 63-18 (F_1)	0.14	47
Porphyre	0.08	67
Potentate	0.39	73
Puck	0.10	67
Pyros (F_1)	0.23	79
Rocket	0.25	67
Saint Pierre	0.10	78
Wintermarmande	0.15	43
Lots producing (quantities<0,10 mg per flower; quality <65% normal grains)		
Coldset	0.01	38
Earlinorth	0.05	44
Fireball	0.01	54
Pearl Harbor	0.02	39
Primabel	0.08	38
Swift	0.05	51
Veecrop	0.01	63

Natural ability to set parthenocarpic fruits

A. Experiment performed

During the 1976 spring cold-house experiment, the Severianin variety showed a remarkable disposition for natural parthenocarpy (Table 2). Contrary to other varieties, vibration does not improve yield in Severianin. This variety is able to produce big fruits when all forms of fertilization are absent.

T a b l e 2. **Performances of Severianin in the cold-house. Spring 1976**

	Open-pollination	After vibration of the inflorescences
Number of fruits set per plant (4 inflorescences)	17.7	17.5
Setting, %	71	73
Average weight of fruit	90	94
Number of seeds per fruit	0	0

Severianin, which was bred in the Moscow area, is known for its ability to set fruit by parthenocarpy. Growth habit of the variety is determinate, and production is early and concentrated. The fruit has green shoulders, it is round to slightly flat with numerous locules (5 to 9) irregularly arranged.

The test conditions in which the experiments were carried out are given in Table 3.

Six experiments were done, 2 with spring glasshouse crops (A and B), 2 with summer outdoor crops (C and D) and 2 with autumn glasshouse crops (E and F). In five of these, average minimum temperatures were much the same and only the unheated glasshouse crop (experiment A) was subjected to lower temperatures.

We compared 3 treatments: 1) Emasculation, without pollination; 2) Self-pollination by hand following emasculation or without emasculation; 3) Pollination by Apédice (a line producing good quality pollen in abundance) following emasculation.

Pollination by hand is accomplished at a more or less early stage in flower development, depending on the experiment (Table 3). The fruits obtained were harvested and then weighed singly and the seeds extracted and counted fruit by fruit. Results are given in Table 4 and fig. 3.

In all six experiments the most important result is that fruits are obtained with the treatment excluding pollination. The setting percentage after this treatment is equal to or slightly lower than that obtained after the two other treatments (Table 4).

In graph 3 we compare two by two, the average weight of fruit within each experiment (Student's test). In the spring and summer experiments the average weight of the fruit obtained without pollination is not inferior, at the 0,05 level, to that of the fruit subjected to the other two treatments. On the other hand, in the two autumn glasshouse experiments (E and F), the fruit weight average obtained without pollination is lower at the 0,05 level than that of the fruit issuing from self-pollination.

T a b l e 3. Experiments with Severianin. Test conditions

Experiment	A	B	C	D	E	F
Time of cultivating	Spring		Summer		Autumn	
Year	1977		1977		1976	1977
Growing method	cold-house open soil	hot-house in pots	outdoor crop open soil		hot-house open soil	
Flowering period: time of flowering	3rd March 4th April	4th March 24th March	9th May 6th June	9th May 7th June	27th Sept. 5th Nov.	27th Sept. 21th Oct.
minimum temperature averages / maximum » »	7°7 / 22°3	~15°0 / 23°9	12°0 / 23°9	12°3 / 24°1	14°8 / 24°4	13°0 / 25°4
Treatments: 1. Emasculation, no pollination	no pollination		no pollination		no pollination	
2. Self-pollination	1 day after emasculation		the day emasculation was carried out		at full bloom, without emasculation	
3. Pollination with Apédice	1 day after emasculation		the day emasculation was carried out			

T a b l e 4. **Experiments with Severianin**

Experi-ment	Treat-ment*	Number of plants	Number of fruits harvested	Setting, %	Average weight of fruit (g)	Average number of seeds per fruit
A	1 2 3	4 4 4	62 61 61	67 66 69	122 118 137	0 6.2 11.9
B	1 2 3	4 4 4	58 60 52	73 90 81	132 124 112	0 14.5 21.1
C	1 2 3	5 5 5	34 34 41	40 40 54	77 93 91	0 45.8 18.6
D	1 2	10 10	61 71	31 43	102 101	0 37.0
E	1 2 3	4 4 4	30 19 42	34 39 45	56 77 60	0 31.6 36.6
F	1 2	2 2	24 21	49 68	83 119	0 171.3

* 1 — Emasculation, no pollination; 2 — Self-pollination; 3 — Pollination with Apédice.

Now, we are unable to give an explanation for the differences observed in the autumn experiments between the average fruit weight without pollination and that of the fruit issuing from self-pollination.

B. Outlook

The type of parthenocarpy found in Severianin is particularly easy to introduce into breeding programs, owing to its monogenic determinism. We have shown (Philouze, Maisonneuve, 1978) that a single recessive gene is involved. We proposed pat-2 (parthenocarpic-2) be used as a symbol for the locus of this gene. We did in fact conclude from the allelism test performed on the parthenocarpic material pat (stock 2524) supplied by Soressi (Italy) (Soressi, Salamini, 1975), that the parthenocarpic character in Severianin is due to a mutation at a different locus to pat. We may point out that the type of parthenocarpy arising from pat does not seem to be of any use, owing to severe female sterility noted in our test conditions. On the other hand, maintenance of Severianin is no problem as selfing occurs naturally under favourable environmental conditions.

We studied the 75/59 parthenocarpic line supplied by Reimann-Philipp (West Germany). Growth habit is determinate in this line which is very early, bearing very small regular round-shaped fruits (20 to 30 g) which ripen uniformly and have 2—3 locules. In the experiments performed with 75/59, similar to those done with Severianin, the seedless fruits obtained after emasculation and no pollination were at least as big as those containing seeds issuing from self-pollination or from pollination by Apédice, whether in spring, summer or autumn crops.

We did the allelism test between Severianin and 75/59. The parthenocarpic character in 75/59 is not due to pat-2 (Philouze, Maisonneuve, 1978). It is controlled by several recessive genes, at least three, according to the tests we have underway. Plants with a rate of parthenocarpy equal to that of 75/59 are difficult to find in progenies springing from this line. It is for this reason that we do not contemplate using 75/59 in breeding programs.

We intend comparing the type of parthenocarpy in Severianin with the parthenocarpic material studied by Ludnikova (1970) and in particular with the Pridneprovskij variety.

Seedlessness in Severianin does not seem to entail any technological defects. We compared seedless fruits (obtained by emasculation and no subsequent pollination) with seed-bearing fruits (obtained through self-pollination by hand). No differences were revealed between the two lots as regards firmness and dry matter content.

We are at present breeding a diversified pat-2 material on which to further our study of parthenocarpy. We shall, in particular, be investigating whether the genotypic context has any effect on the degree of expression of the parthenocarpic character.

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СЕЛЕКЦИЯ ТОМАТОВ НА СПОСОБНОСТЬ ЗАВЯЗЫВАТЬ ПЛОДЫ ПРИ НИЗКИХ ТЕМПЕРАТУРАХ

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Один из важных факторов, ограничивающих завязывание плодов при низких температурах, — это необходимость выработки достаточного количества высококачественной пыльцы. Работа, которую мы проводили за последние два года по выведению сортов, способных завязывать плоды при низких температурах, велась по двум направлениям:

1) изучение способности коллекции сортов производить достаточное количество высококачественной пыльцы;

2) изучение естественной способности завязывать партенокарпические плоды.

1. Способность производить достаточное количество высококачественной пыльцы

В 1976—1977 гг. изучалась большая коллекция сортов. Во время цветения в течение нескольких недель температуры варьировали от 5 до 10° С. Несколько раз во время роста посевов измеряли количество пыльцы, производимой на цветок. Образец собранной пыльцы наблюдали in vitro после окрашивания ацетокармином. Далее, взяв каждый сорт отдельно, изучали урожайность растений, на которых несколько раз во время цветения проводили покачивание соцветий. У сортов была хорошая согласованность при классификации, во-первых, по количеству вырабатываемой пыльцы и ее качеству; во-вторых, по количеству пыльцы и урожайности на растение. Из 10 изучавшихся сортов такие, как Supermarmande, Vendor и несколько линий, выведенных в Монфавэ, производили большое количество высококачественной пыльцы и давали высокие урожаи в холодном помещении. С другой стороны, Earlinorth, Goldset, Fireball, Swift в таких же условиях давали небольшое количество пыльцы низкого качества и низкие урожаи.

Тесная согласованность сортов при классификации их по изучавшимся факторам (количество и качество пыльцы, урожайность) подтверждает обоснованность проводимой нами работы по введению испытания на основе оценки in vitro качества пыльцы, образованной при воздействии низких температур. Это испытание должно быть быстрым и надежным, позволяло бы классифицировать сорта, а также обеспечивало хорошее согласование такой классификации с оценкой тех же сортов, выращиваемых в холодном помещении. Растения выращивали при обычных температурах вплоть до начала периода цветения, а затем помещали в камеру с контролируемой температурой на 5 дней при 7° С круглосуточно. Затем их вновь возвращали в условия обычной температуры. Пыльцу исследовали через 8—14 дней после возвращения из холодильника. Это испытание позволяет отобрать большой материал для получения родителей, способных вырабатывать высококачественную пыльцу при низких температурах.

2. Естественная способность к завязыванию партенокарпических плодов

Во время предшествующих испытаний в холодном помещении советский сорт Северянин показал выдающуюся способность к естественной партенокарпии. Изучая сорт Северянин, мы нашли, что склонность этого сорта к партенокарпии проявлялась при самых различных условиях роста — при полевом или тепличном посеве, весеннем и осеннем посеве, выращивании к ст. Ж.Филюз, Б.Мезоннева.

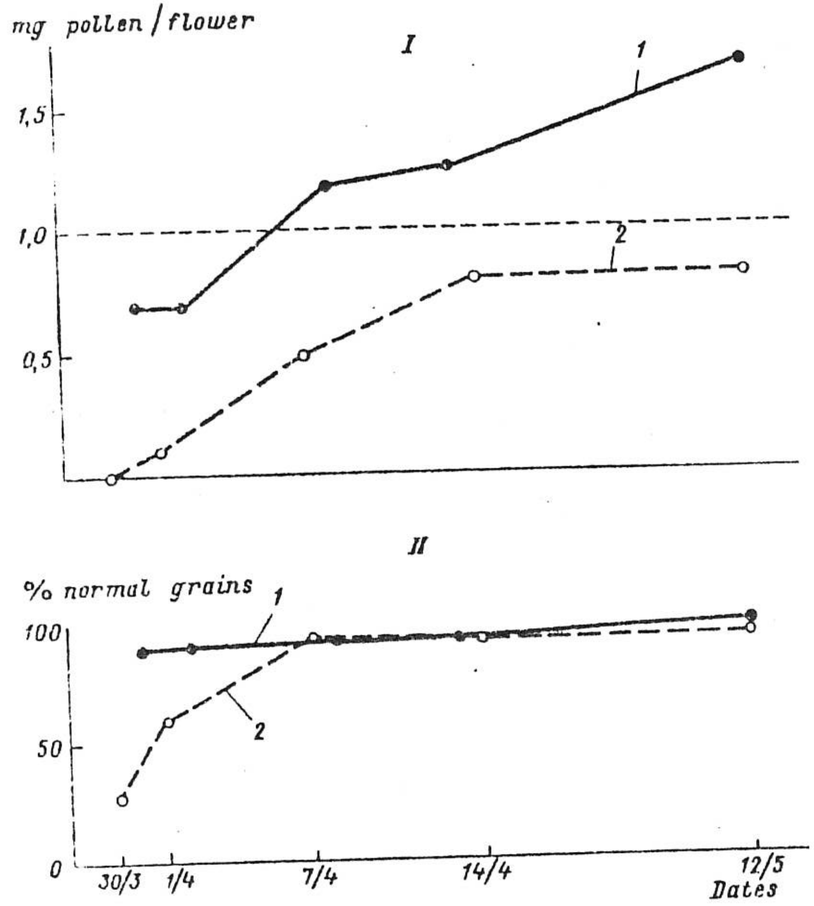

Fig.1. Quantity and quality of pollen produced by 2 varieties at different dates.Cold-house. Spring 1976.
I – quantity of pollen ; II – quality of pollen.
1 – Apedice 2 – Earlinorth.

при низких, средних или высоких температурах. Сохранение сорта Северянин путем естественного самоопыления не представляет проблемы, поскольку семена можно получить в оптимальных условиях роста.

Мы показали, что партенокарпический признак у сорта Северянин контролируется рецессивным геном, который мы предложили обозначить как pat-2 (партенокарпический-2). Испытание аллелизма с партенокарпическим материалом pat, доставленным Соресси, Италия (материал 2524), позволило нам сделать вывод, что партенокарпический признак у сорта Северянин является следствием мутации в различном локусе к pat. Тип партенокарпии, возникающий из pat, по-видимому, не представляет ценности вследствие сильной женской стерильности.

Мы проводили испытание аллелизма между сортом Северянин и партенокарпической линией 75/59, доставленной Рейманн-Филиппом (Западная Германия). Партенокарпический признак у 75/59 не является следствием pat-2. Он контролируется несколькими рецессивными генами.

Мы продолжаем изучение партенокарпии у сорта Северянин и 75/59. Тип партенокарпии у этого сорта, по-видимому, уже заслуживает включения в селекционную программу.

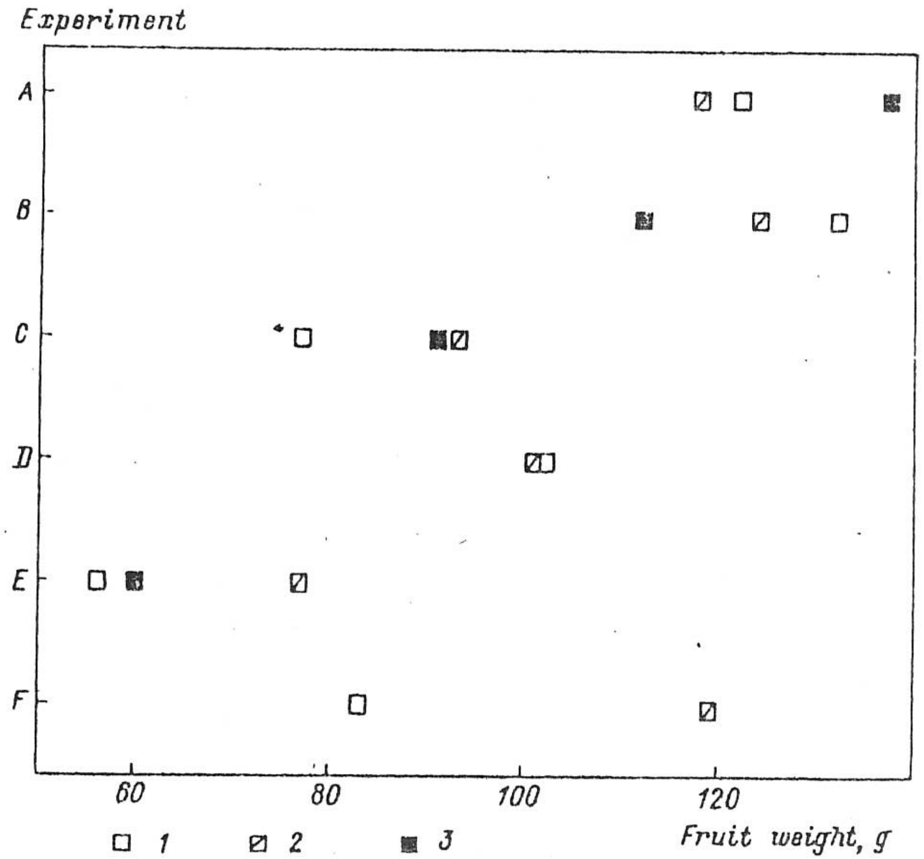

Fig.3. Average weight of fruit from Severianin. Within each experiment, everages are compared 2 by 2, using student's t test.
1 - emasculation no pollination, 2 - self-pollination, 3 - pollination with Apédice.

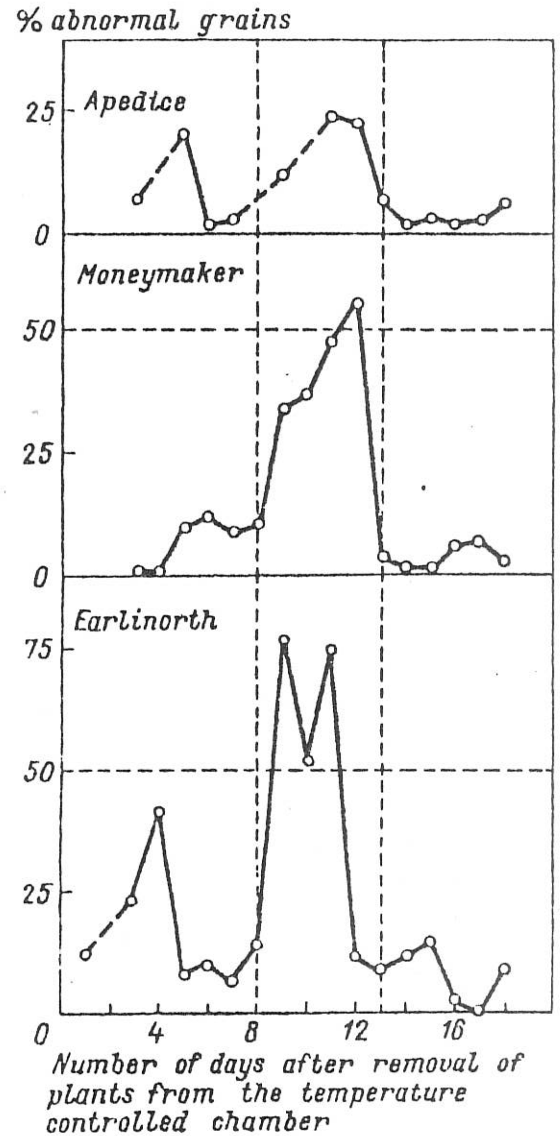

Fig.2. Quality of pollen produced by 3 varieties when kept for 5 days at a temperature of 7°C day and night.