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POOR FRUIT SETTING IN STRAWBERRIES. I

CAUSES OF A POOR FRUIT SET IN STRAWBERRIES IN GENERAL

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ABSTRACT

In 1949 at least one of the Jucunda strawberry clones selected in the Netherlands was found to have a strong tendency to bad fruit setting, causing malformed fruits, "nubbins", and resulting in entire or partial crop failure. This phenomenon was by no means new and has since been of more or less frequent occurrence.

In the present paper a survey is given of the possible causes of a poor fruit set in strawberries in general; in a second article the investigations of the Jucunda variety will be dealt with.

External causes of poor fruit setting are spring frost during the blooming period; damage caused to flowers by parasites, either insects, mites or fungi; unfavourable weather conditions during flowering; in growing under glass insufficient air circulation and insufficient pollination by bees due to keeping the frames closed too much; insufficient pollination in overcrowded beds; and unfavourable structure of the soil. However, these external factors can be eliminated to some extent by cultural measures.

Therefore a more serious problem is presented by sterility or incomplete fruit setting, which is very complicated and determined genetically. Genetically, two types of strawberries can be distinguished: the all-female type, which is heterozygous for the sex factor, and the more or less hermaphrodite-male type, which is homozygous for that factor. In this latter group all kinds of intermediate forms are encountered between the all-male type with entirely sterile pistils and the almost entirely female type with only very few stamens.

A good variety should have both well-developed stamens and entirely fertile pistils. Besides a fairly large number of varieties of which the stamens are well- or fairly well-developed and which have a high to moderate percentage of good pollen, there are some varieties of which the stamens are usually much less developed and which produce only a low percentage of good pollen.

Pistil-sterility is reflected on the one hand in all pistils of one or more of the later flowers of the inflorescence failing to set, owing to which the receptacle does not swell and berries are not developed. This phenomenon is regularly encountered in seedlings. On the other hand a certain number of the pistils of a flower may fail to set, resulting in malformed fruits.

1. INTRODUCTION

In 1949, in different localities in the Netherlands, a very poor fruit set occurred in a clone of the strawberry variety Jucunda, the most important processing strawberry in our country, which still accounts for about 40 % of the total production. It was found

that a poor setting of fruit is not restricted to this one clone, but under unfavourable conditions may occur in all Jucunda clones.

Since that time poor fruit setting in Jucunda has often been prevalent, notably in the years 1955 and 1957. In some years difficulties of fruit set may also occur in other varieties, but seldom to such an extent as in Jucunda. As poor setting may result in malformed fruits and crop failure, this problem is a very serious one. Therefore we have carried out further investigations on this problem, the results of which will be summarized in two papers.

A large number of persons have collaborated in this work, either directly or indirectly. At the Institute of Horticultural Plant Breeding J. P. BRAAK carried out an investigation of response to low temperatures (see part II), A. E. ZEILINGA determined the quality of the pollen, J. H. A. FERGUSON and Miss F. GARRETSEN helped with the mathematical and statistical analysis. Special acknowledgement is also due to the Horticultural Advisory Services of the provinces of Noord-Brabant and Zeeland, which took an active part in the field trials with Jucunda in 1951 and 1952.

Furthermore much information and help have been received from various other Advisory Services and growers.

2. THE SYMPTOMS

Soon after flowering it will be noticed that the flower clusters do not bulge out, as in a normal fruit set, but remain erect. The receptacle, carrying the ovaries, swells but little, because many seed buds have not set and remain small. Only the receptacle under the fertilized pistils develops into the coloured flesh, forming the pseudocarp called "strawberry". In this way the malformed berries or "nubbins" are formed, which often ripen later than the normal fruits (Fig. 1). The total yield is small and picking does not pay, because the crop is of inferior quality.

This phenomenon of the "petrified" fruits in Jucunda is not new. At Beverwijk, in the Kennemerland-area, it was responsable for the failure of the strawberry crop in 1923 where Jucunda was then a leading variety. Yet in recent years this phenomenon has become more noticeable. This is ascribed partly to the fact that the strawberry is receiving increased attention by research workers, extension services and breeders, so that deviating symptoms are noticed sooner; and partly to the losses in recent years having been greater.

In previous years Jucunda fields consisted of mixtures of unselected or, at best, mass-selected plants. After the war a start was made with more intensive clone selection. Thus a large improvement was achieved in the health status and productivity of the crop, but the fact cannot be denied, that this also entails risks for a relatively unreliable cropper like Jucunda. In 1949 for instance one of the clones selected in the Province of Noord-Brabant, called JK 3, a vigourous and profusely flowering clone, entirely failed as a result of poor fruit setting. In that year vast fields under this clone were unproductive. From this lesson the conclusion was drawn that it is safer to introduce mixtures of selected clones, instead of separate clones of Jucunda. Although clone JK 3 was, of course, immediately taken out of propagation, it was found that in 1955 this clone was still being propagated and sold by some private propagators. Again various growers incurred losses from poor fruit setting in Jucunda. Since that time the chances of such

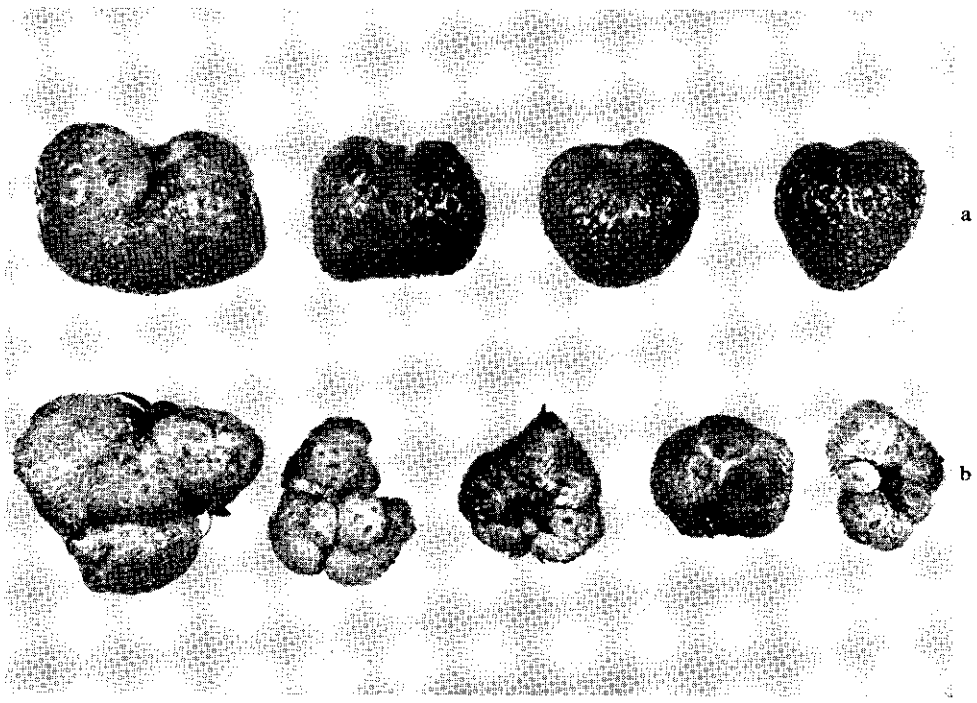
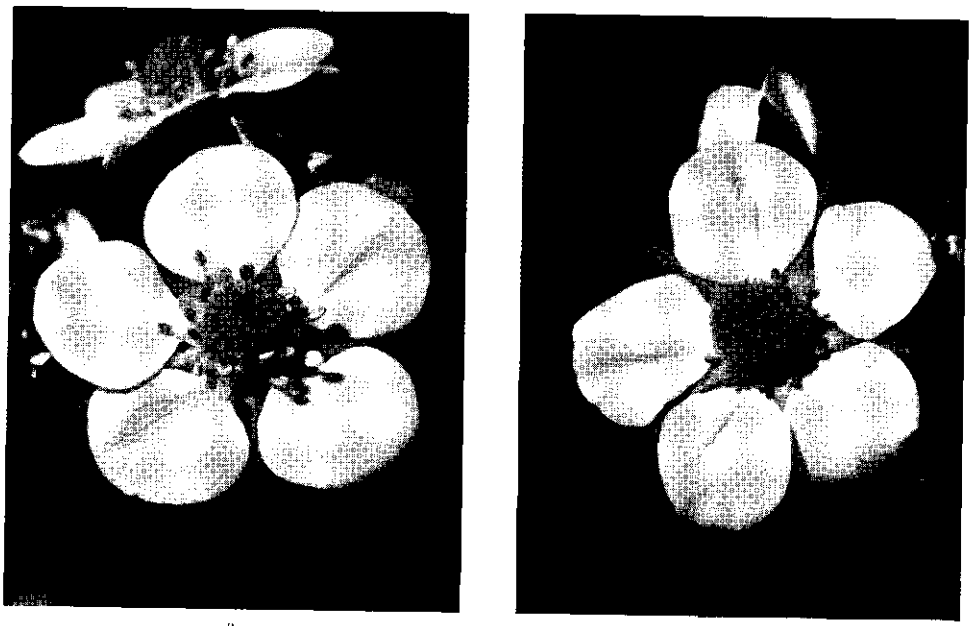


FIG. 1. JUCUNDA STRAWBERRIES: a. WELL DEVELOPED BERRIES; b. MALFORMED BERRIES OR "NUBBINS"

FIG. 2. NIGHTFROST DAMAGE OF FLOWERS



a b

FIG. 3.

a. FLOWER WITH WELL-DEVELOPED STAMENS. b. FLOWER WITH NEARLY COMPLETELY ABORTED STAMENS

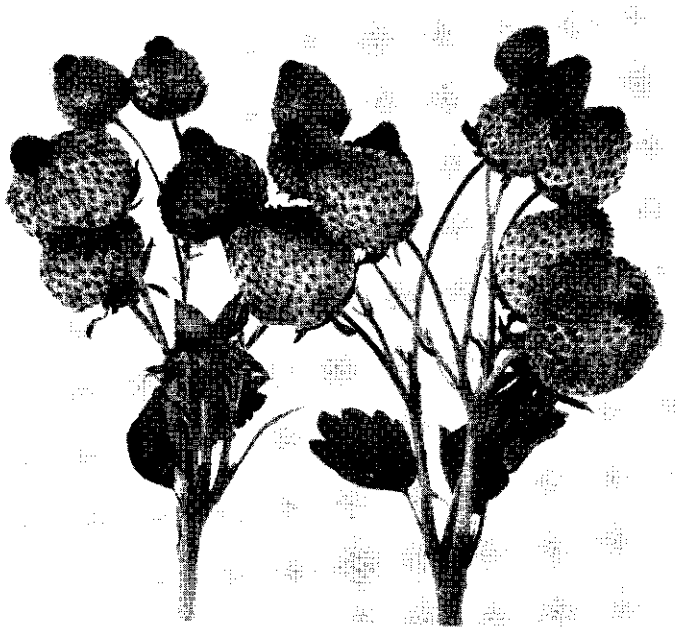
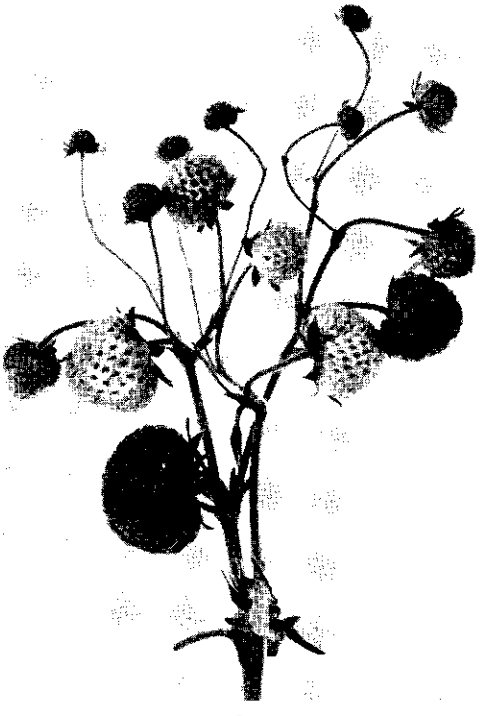
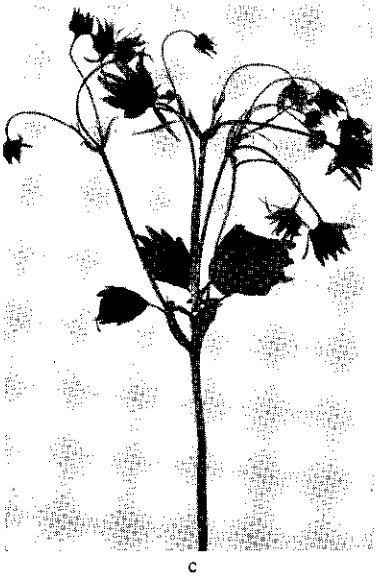


FIG. 4. STERILITY OF THE TIP OF THE BERRIES.



a

b



c

FIG. 5. a. ALL FLOWERS HAVE SET WELL.

b. ONLY THE PRIMARY AND SECONDARY FLOWERS HAVE SET WELL; THE LATER ONES ARE MORE OR LESS STERILE.

c. THE WHOLE INFLORESCENCE IS STERILE.

disapproved clones being propagated have been considerably reduced, as the Netherlands Inspection Service for Arboriculture (N.A.K.-B.) decided to certify only recognized clones in the higher certification classes.

3. Causes of poor fruit setting in strawberries in general

3.1. External causes

3.1.1. Night frost

Night frost just before, during or after bloom can destroy the young pistils, which turn black (Fig. 2). If all the pistils in a flower are frozen the entire receptacle cannot develop and dries out. If only a number of the pistils of a flower become frozen, the other pistils may set; but only that part of the receptacle swells which carries fertilized pistils. This results in malformed fruits.

Some varieties are highly susceptable to night frost, e.g. the early flowering Madame Lefeber and the late-flowering Madame Moutot. Climax is not very susceptible, while the late Jucunda is hardly ever damaged by night frost. Some selections of the wild growing *Fragaria virginiana* in America also carry some resistance against night frost.

Not only the susceptibility of the flowers themselves, but also the position of the flowers in relation to the leaves and the density of the leaves have an effect on the damage. In Climax the flowers are located under a compact mass of leaves and are consequently better protected than in Oberschlesien, whose flowers protrude beyond the leaves.

The injury caused to flowers by winter frost has been left out of account here, as such flowers do not appear at all or only develop a little, but never come into flowering.

3.1.2. Flowers damaged by parasites

Insects and mites can damage the pistils of the flowers so that these cannot set. We saw an example in 1951 when we visited strawberry fields at Geneva (N.Y.) in America. Notably Fairfax showed many "nubbins". The cause of it was not yet known there, but in 1952 the entomologist F. G. Mundiger discovered that this damage was caused by bugs (8).

Strawberry mites (*Tarsonemus pallidus* Banks) sometimes suck at the flowers and thus damage the pistils. As strawberry mites in our country are not yet very active in the open ground during flowering in May, they do not give us much trouble in this respect. In growing strawberries under glass, particularly in autumn production, attack by mites may have a substantial effect on fruit set; so it is of the utmost importance to use plants that are entirely free from mites.

Some time ago Ford and Wilhelm in California discovered that a fungus of the family of the *Moniliaceae* may also cause misshapen fruits (4). The fungus parasitizes on the pistils of the strawberry flowers and can thus impede fertilization.

Great losses may also be incurred if the plants are badly affected by leaf spot (*Mycosphaerella fragariae*) and leaf scorch (*Diplocarpon earliana*), especially when not only the leaves, but also the flowers are affected, owing to which the berries may be kept from setting (7).

3.1.3. Other unfavourable conditions

Inclement weather during bloom. From various experiments and data the impression is gained that cold weather with much rain and wind during bloom is very unfavourable for fruit setting in strawberries. There appears to be great variation in susceptibility between varieties. Auchincruive Climax, selected in Scotland, is rather resistant to bad weather conditions during the blooming season; Jucunda on the other hand is very susceptible. Most varieties hold an intermediate position in this respect and do not present any problems except under very unfavourable conditions, such as prevailed in May 1955. Early in May of that year flowering proceeded normally at first, but later a spell of cold, showery weather set in, which had an adverse effect on fruit setting. This was reflected in the harvesting period, which did not proceed regularly, but lacked "a layer of fruits". Unfortunately usable data on the above are not available, so that we cannot say whether ripening was only delayed, or whether the flowers from the cold period were "petrified", in other words had not developed further.

In table 1 the beginning of flowering is indicated for 1949–1957 in an early, a midseason and a late variety; furthermore the average temperatures (averaged from 8, 14 and 19 hrs local time) in the three decades of May, and the "normal" temperatures, interpolated from data of 1921–1950.

TABLE 1. FIRST BLOOMING DATES IN SOME STRAWBERRY VARIETIES AT WAGENINGEN, COMPARED WITH AVERAGE DAYTIME-TEMPERATURES AT DE BILT

	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958
Deutsch Evern (early)	30/4	5/5	5/5	29/4	27/4	10/5	10/5	19/5	27/4	10/5
Oberschlesien (midseason)	9/5	13/5	16/5	5/5	?	12/5	19/5	21/5	7/5	17/5
Jucunda (late)	12/5[1])	13/5	19/5	12/5	4/5	12/5	19/5[1])	22/5	±7/5[1])	22/5

Decade	Normal temp.	Average daytime-temperature during decade								
April III	11.1	11.1	8.4	10.5	11.0	11.4	9.4	11.2	8.0	11.8	10.5
May I	12.9	11.5	13.2	13.3	16.4	**11.6**	12.7	12.9	14.4	8.9	14.2
May II	14.3	**13.3**	**14.5**	13.0	**15.5**	**15.5**	**15.1**	9.3	12.2	**14.2**	12.4
May III	15.4	**14.4**	**15.1**	**14.7**	**13.4**	**16.7**	**15.7**	**11.7**	**16.0**	**12.3**	**14.3**

[1]) Years of bad fruit setting in Jucunda.
Temperatures corresponding with the blooming period of Jucunda are bold marked.

From the table it appears that the average temperature per decade during the blooming period of Jucunda is 13–17 °C. Lower temperatures occurred in the third decade of May 1955 and 1957; during these years fruit setting was poor. This is an indication that a low temperature may have an adverse effect on setting. However in 1949, when setting was also poor, the temperature during the blooming period, the second and third decade of May, was about normal.

Insufficient pollination under glass. When growing strawberries under glass complete lack of wind may also cause insufficient fertilization. If during flowering the frames are kept closed too much for fear of loosing warmth, the circulation of the air is insufficient to effect a good pollination. Insects too are then excluded; it is notably the early-flowering strawberries under glass which may be much visited by bees. In a trial in the experimental garden at Zaltbommel with frame strawberries of the variety Deutsch Evern the best setting was obtained by opening the frames as wide as possible and applying a mist over the plants which set them in movement. The insects thus obtained ready access to the flowers too (1).

Insufficient pollination in overcrowded beds. Growing in beds is specially suited for varieties and growing conditions in which only a fair amount of foliage is produced. Varieties and selections which produce so much foliage that the flowers and fruits are kept hidden underneath a thick mass of leaves are less suited for this cultivation. In many cases this also applies to peat and sandy soils on which foliar development is usually more vigorous than on clay. The flowers of overleafy plants cannot be sufficiently pollinated, the result being that they do not develop at all, or produce malformed berries.

Unfavourable soil structure. Unfavourable structure of the soil may also cause poor fruit setting of the young berries. The Horticultural Advisory Service at Amsterdam established from investigations of soil profiles, that "petrifaction" of the fruits of frame strawberries (Deutsch Evern) was often associated with a poor soil structure (14). The profile of the peaty soil was then spotty; at a depth of 40 cm it mostly consisted of a tough greyish mass. Such soils remain long cold and give off little warmth, especially at night. The actual cause of poor fruit setting is thought to lie in too low temperatures. The growers are advised in such cases to improve the structure of their soil, which will at the same time effect an improvement in the supply of warmth.

In the Province of Noord-Brabant similar experiences have been gained with outdoor varieties on soils with hard "peaty" spots in the subsoil.

As early as 1927 DARROW pointed out that fertility in strawberries can be greatly influenced by the soil type (3). In Oregon the flowers of the variety Ettersburg 121 were sterile on sandy soil, but on fairly heavy clay the variety was sufficiently productive. Also the wild *Fragaria chiloensis* and Little Scarlet, a selection of *Fragaria virginiana*, appeared to be highly sensitive to the soil. *F. chiloensis* was sterile on good garden soil, but gave a good set of fruit on sterile volcanic soil; Little Scarlet was much more productive on clay at Geneva (N.Y.) than on the sandy soils at Glenn Dale (Wash., D.C.). It is difficult to say on what factors these differences depend.

Thus it appears that the process of fruit setting in strawberries depends on various growing conditions. A distinction should be made between the influence on fruit setting process itself during bloom, and the influence of the growing-conditions on the initiation and development of the flowers during the period between bloom and during the proceding period. In order to find out on what factors the above practical experiences are based, further physiological research is necessary.

3.2. Internal causes

3.2.1. Introduction

Apart from the external factors (which can influence fruit setting) the causes of a poor set can also be inherent in the plants themselves and be genetically determined. There are many possibilities, but it is only on a few of them that more detailed information is available. There may also be an effect of viruses, with which many strawberries are infected. No facts are yet known which indicate that certain virus diseases especially manifest themselves in a poor fruit set in plants that are otherwise vigorous.

Genetically, two sex types are known in the strawberry, namely the purely female type, which is heterozygous for the sex factor and never develops any pollen, and a hermaphrodite – male type, which is homozygous for this factor.

In the cultivated octaploid strawberry varieties only the hermaphrodite varieties are of importance. The few female varieties, for which a pollinator has to be available, such as Mieze Schindler, Tardive de Leopold and Macherauchs Späternte, are not suitable for growing on a large scale and can be left out of account here. Morphologically and physiologically hermaphrodite strawberries form a very heterogeneous group; all types of intermediate forms can be found in it, from the purely male type with sterile pistils to the practically female type with only sporadically well-developed stamens.

E. SCHIEMANN, who has carried out extensive research on sex problems in diploid and polyploid species, found among her material a number of plants differing both in pistil- and in stamen-sterility (10). She assumes that this phenomenon depends on a number of sterility factors. Some of these types were investigated anatomically by C. F. RUDLOFF (9). He found that the development of the seed buds and of the anthers could cease at widely different stages, which corresponded with the male and female sterility series, established by SCHIEMANN.

Our research was limited to the cultivated octaploid strawberry varieties ($2n = 56$). Hence the question of sterility from crosses between species with varying numbers of chromosomes is left out of account here.

3.2.2. Stamen sterility

In purely female varieties the stamens form small sterile staminodia and then do not develop further. They never carry any pollen. In hermaphrodite types we may encounter numerous intermediate forms from types with well-developed stamens to more or less aborted stamens with reduced or shrivelled anthers, carrying little or no pollen. The quality of the stamens depends on the variety, the stage of flowering and the temperature.

The variety. There are a good many varieties with mainly good stamens, e.g. Deutsch Evern, Laxton van Glanerbrug, Georg Soltwedel and Suikeraardbei (= Königin Luise). A few other important varieties often have poorly developed stamens, e.g. Jucunda and Madame Moutot. Between these extremes there are numerous intermediate forms, sometimes with moderate, sometimes with good stamens, such as Oberschlesien, Macherauchs Frühernte, Madame Lefeber and Ydun (see Table 2 and 3). This is a point of consideration in the judging of varieties.

The stage of flowering. In the first flowers to open the stamens are often less developed than in the later blossoms.

The temperature. In some varieties the stamens develop better in warm than in cold weather. In 1944 we estimated the quality of the stamens in a number of varieties on May 26, after ten days of cold weather, and on May 31, at the end of a period of warm weather (Table 2). In various varieties the percentages of good stamens had markedly increased after a week of warm weather.

TABLE 2. PERCENTAGE OF GOOD STAMENS AT WAGENINGEN ON MAY 26 AND 31, 1944

Varieties	Beginning of flowering	Percentage good stamens	
		26/5	31/5
Early			
Deutsch Evern	1/5	100	100
Laxton van Glanerbrug (= Amazone)	24/4	100	100
Madame Lefeber	10/5	100	100
Sieger	12/5	75	100
Midseason			
Roem van Ieperenburg	10/5	60	100
Oberschlesien	18/5	60	80
		50	100
Suikeraardbei (= Königin Luise)	10/5	100	100
Late			
Jucunda	16/5	75	100
Madama Moutot	16/5	25	60

3.2.3. The quality of the pollen

A point of separate discussion is formed by the quality of the pollen itself. VALLEAU (13) and HEROLD (5) have observed that in addition to normally developed pollen grains a larger or smaller number of degenerated grains may occur in strawberry pollen. The amount of aborted pollen, despite great variation, is more or less typical of the variety. In a number of varieties counts have been made in different years, of the amount of morphologically good pollen. This, of course, only gives some information on the maximum amount of grains which can germinate.

Germination experiments were not made by us. Even the percentages of morphologically good pollen in different samples of one and the same variety were found to fluctuate to such an extent that there seemed to be little point in determining the germination percentages. Nevertheless it was done by HEROLD, who found a strong correlation ($r = \pm 0.675$) between the percentages of morphologically good grains and germinating grains.

At first the pollen grains were counted in lactic acid, later in Belling's carmine acetic acid-glycerin, which colours the good grains red. In all cases samples of 3×100 grains were counted.

The experiences of VALLEAU and HEROLD could be confirmed. The percentages of good pollen of one and the same variety varied widely. For example, in 8 different

samples of Deutsch Evern taken on 28 April and 4 May 1948 we found quantities of good pollen ranging from 37 % to 82 %. Notably the first flowers often have many bad pollen grains.

We, too, have found that within very wide limits the quality of the pollen is typical of the variety. Although we have only one pollen analysis at our disposal for certain varieties, we have divided them into three groups on the basis of the figures given in table 3.

Group I. Varieties which usually have a high percentage of morphologically good pollen.

Group II. Varieties with a moderate, but seldom very low, percentage of morphologically good pollen.

Group III. Varieties with a low to very low percentage of good pollen.

For comparison the figures of HEROLD, which fairly closely agree with ours, are added.

The last column of table 3 shows the quality of the stamens, recorded during full bloom in 1949 and 1952. In Group I and II the stamens are usually good to fairly good, but in group III they are mostly poor. This indicates that stamen-abortion and a low percentage of good pollen may be governed by the same factors. This seems to be confirmed by the fact that both the stamens as a whole and the pollen grains are better in the later flowers than in the first ones to open.

It might be questioned whether pollination with insufficiently good pollen will actually bring about an unsatisfactory or poor setting of fruit. As far as we know there are no examples in the Netherlands of a poor setting due to inferior pollen in the varieties of group I, which have a high percentage of good pollen. In the varieties of group II, with a moderate percentage of good pollen, cases of insufficient fruit set are seldom encountered. On one occasion, however, we saw a very poor set of fruit in crowded beds of Ydun. In Oberschlesien, which has been an important variety in the Kennemerland area since about 1930, poor setting may occasionally occur.

At the time the experiences with Oberschlesien in England were very unfavourable (11, 12). Round 1930 Oberschlesien was often interplanted as a pollinator in fields of the female variety Tardive de Leopold in S.W. England. The results were disappointing, owing to the inability of Oberschlesien to provide adequate cross-pollination. It was found that Oberschlesien was partially self-sterile itself. Even when it was pollinated daily with its own pollen, it produced many slightly malformed fruits, while pollination with Royal Sovereign and Huxley resulted in normal, regular fruits.

The different behaviour of Oberschlesien cannot be explained. Possibly the English-grown strain of this German variety was different from that grown in the Netherlands.

In group III, with a low percentage of good pollen, only 2 varieties are encountered, Jucunda and Madame Moutot. Poor fruit set may occur in both; in Jucunda to such an extent, however, that it was subjected to further investigation (Part II).

In a number of varieties self fertility was investigated by HEROLD, by bagging and tapping the flower trusses both of plants growing in the open and potted plants. On the basis of his results he divided the varieties into 6 fertility groups. In table 3 these are shown for a few varieties.

Contrary to expectation these groups do no coincide with the degree of pollen degeneration. This is most noticeable in the variety Madame Moutot, which, despite

its poor pollen, belongs to the best fertility group. Deutsch Evern, with very good pollen, falls in fertility group 3, which is only sufficiently self-sterile. This seems to indicate that very little good pollen can suffice for a good fertilization. Evidently other factors are decisive for successful fertilization.

TABLE 3. PERCENTAGES OF MORPHOLOGICALLY GOOD POLLEN FROM OUTDOOR STRAWBERRY VARIETIES AT WAGENINGEN COMPARED WITH THOSE OF HEROLD; AND QUALITY OF STAMENS AT FULL BLOOM

Varieties	% morphologically good pollen						Self-fertility group HEROLD[1])	Quality of stamens at full bloom in 1949 and 1952
	1944	1948	1950	1951	1953	Herold		
Group I (a high % of good pollen)								
Bowa	–	–	–	–	80	–	–	good
Deutsch Evern	74–91	37–82	61	–	94	80	3	good
F. chiloensis ♂	97	–	–	–	–	–	–	good
F. vesca semperflorens	90	–	–	–	–	–	–	fair
Roem v. Ieperenburg	67	–	64	–	–	–	–	rather good
Laxton van Glanerbrug (= Amazone)	82	58–96	–	–	–	84	2	good
Regina	–	–	–	–	94	–	–	good
Scarlet	85–90	–	–	–	–	–	–	good-rather good
G. Soltwedel	–	–	95	–	–	–	–	fair-good
Suikeraardbei (= Königin Luise)	45–95	77	63	–	–	68	4	good
Group II (an intermediate % of good pollen)								
Roem van Breda	–	–	39	–	–	–	–	rather good-good
Climax	–	–	38	–	69	–	–	rather good
Madame Lefeber	27–71	–	–	–	–	57	1	rather good
Macherauchs Frühernte	–	–	–	–	48	–	–	rather good
Oberschlesien	35–47	–	17	–	21–24	27	3	poor-rather good
Ydun	–	–	–	–	36	–	–	very poor-fair
Hansa (= Zwartkop)	58	–	25	–	–	54	3	fair-good
Group III (a low % of good pollen)								
Jucunda	11–29	–	4–41	4–21	2–9	–	–	poor
Madame Moutot	11–47	–	16	–	7	41	1	poor-rather good

[1]) Self-fertility group 1 = very highly self fertile.
„ „ „ 6 = practically self-sterile.

3.2.4. Insufficient pistil-fertility

In 1927 DARROW (3) stated that "pistil-sterility" of hermaphrodite varieties is the only important type of sterility in the strawberry. He regarded it as one of the outstanding problems in the development of the strawberry.

Complete pistil-sterility only occurs in purely male plants, as are encountered in some wild species (*F. moschata*, *F. chiloensis*, *F. virginiana*). In breeding one may come

across numerous intermediate forms in seedling populations from the purely male types to entirely hermaphrodite plants (Fig. 5).

There are cases in which the primary, and sometimes also the secondary flowers of the inflorescence set well, but the following flowers are sterile. It also happens that only the last flowers in the truss are sterile, e.g. in the variety Bowa. Another kind of sterility was encountered in plants of which only the top of the fruits had not set (Fig. 4).

The female tendency is the strongest in the primary flowers of the inflorescence; it decreases in the flowers of a higher order. Stamen-fertility, on the other hand, tends to increase in the flowers of a higher order of the inflorescence, which flower later than the primary and secondary ones.

According to DARROW, about 1850 fruit setting in the hermaphrodite varieties in America was only 15–20 %. By discarding the little fertile varieties and breeding sufficiently fertile varieties it has since been possible to increase the fertility and thereby the productivity. In order to obtain the highest possible degree of productivity it is necessary that all flowers set well and develop into good, evenly shaped berries.

In numerous crosses between all kinds of octaploid strawberry varieties no sterility by incompatibility has been found. As a rule such crosses were successful; only when using Jucunda as a mother-plant the setting was sometimes less good. Under glass in some casses little or no good pollen was obtained, both in Jucunda and in a few seedling-strains.

SAMENVATTING

Slechte vruchtzetting bij aardbeien

I. Oorzaken van een slechte vruchtzetting bij aardbeien in het algemeen

In 1949 bleken er onder de in Nederland geselekteerde klonen van het aardbeiras Jucunda één of meer voor te komen met een sterke neiging tot slechte vruchtzetting, resulterend in misvormde vruchten, en daarmee in een gehele of gedeeltelijke misoogst. Dit verschijnsel was geenszins nieuw, en is ook sindsdien herhaaldelijk meer of minder ernstig opgetreden.

In dit eerste artikel wordt een overzicht gegeven van de mogelijke oorzaken van een slechte vruchtzetting bij aardbeien in het algemeen, in het tweede artikel zal het onderzoek over het ras Jucunda worden besproken.

Als uitwendige oorzaken van een slechte zetting zijn te noemen: nachtvorst in de bloeitijd; beschadiging van de bloemen door parasieten, hetzij insekten of mijten, hetzij fungi; ongunstige omstandigheden tijdens de bloei, zoals guur weer; onvoldoende luchtbeweging en bijenbezoek bij de glasteelt door het te veel gesloten houden van de ramen; onvoldoende bestuiving in een te dicht gewas; een slechte struktuur van de grond. Deze uitwendige faktoren zijn evenwel in meerdere of mindere mate door cultuurmaatregelen op te heffen.

Ernstiger is daarom de steriliteit of onvolkomen vruchtzetting die genetisch bepaald en zeer gecompliceerd is. Genetisch kunnen bij de aardbei twee typen worden onderscheiden: het volkomen vrouwelijke type, dat heterozygoot is voor de geslachtsfaktor, en het hermaphrodiete – manlijke type, waarin de geslachtsfaktor homozygoot is. Deze

laatste groep is verreweg het belangrijkste en grootste. Er worden alle overgangen in gevonden van het volkomen manlijke type met geheel steriele stampers en fertiele meeldraden, tot het vrijwel geheel vrouwelijke type met fertiele stampers en slechts enkele fertiele meeldraden.

Een goed ras moet zowel goed ontwikkelde meeldraden hebben als goed functionerende stampers. Naast een tamelijk groot aantal rassen met goed tot vrij goed ontwikkelde meeldraden en voldoende goed stuifmeel, komen er enkele rassen voor met veel slecht ontwikkelde meeldraden en een laag percentage goed stuifmeel (tabel 2 en 3).

Steriliteit van de stampers kan tot uiting komen in het niet zetten van de zaadknoppen in één of meer bloemen van hoger orde in de bloeiwijze, waardoor opzwelling van de bloembodem achterwege blijft en geen aardbeien ontstaan. Dit verschijnsel komt geregeld in zaailingen voor. Ook kan zich het geval voordoen, dat een deel van de stampers uit een bloem niet zet; hierdoor ontstaan misvormde vruchten.

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POOR FRUIT SETTING IN STRAWBERRIES. II

MALFORMED FRUITS IN JUCUNDA

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ABSTRACT

1. This is a report on a preliminary investigation of the causes of insufficient fruit setting in the strawberry variety Jucunda, especially its clone JK3
2. From field experiments in different localities it was concluded:
   a. that raw weather increases the percentage of malformed fruits (nubbins) in Jucunda, especially in clone JK3, and
   b. that interplanting with a good pollen variety (Deutsch Evern) may decrease this percentage.
3. An insufficient pollination may take place in the centre of too closely planted beds.
4. Bees do not improve fruit setting in Jucunda.
5. Usually the development of good anthers in Jucunda is not abundant, which means that the quantity of pollen produced is not large.
6. The quality of the pollen, expressed as a percentage of morphologically good pollen, of the bad clone JK3 was sometimes a little lower than that of the good clones of Jucunda.
7. Meiosis in the anthers of clone JK3 was normal.
8. The fruit setting of the variety Deutsch Evern was good at all temperatures of the range of 10–26 °C, whereas that of Jucunda was only good at 17–26 °C. At 14 °C and lower the fruit setting in Jucunda was reduced to zero.
9. As the phenomena of this type of unfruitfulness are greatly influenced by the growth conditions of the plants, further investigation of this problem will be carried out under controlled conditions.

1. INTRODUCTION

In a former article (4) some factors have been discussed which in general can unfavourably influence the fruit setting in strawberries.

Against this background the problem of reduced fertility in the variety Jucunda and especially in its clone JK3, has been studied. As some indications for the best way of further research have been found now, this first orientating phase of our investigations is herewith closed. The results of this preliminary study are reported in the present article.

2. Fruit setting of Jucunda under different natural conditions

Trials in different localities

There are growers who think that cold (rainy?) weather during flowering may cause a poor fruit setting in Jucunda. To test the correctness of this opinion field plots were laid out in 1952 and 1953 in four localities with a somewhat different climate:

a. At Middelburg (Zeeland), on a clay soil, in open windy land, not far from the sea.

b. At Woensel (near Eindhoven), on sandy soil, sheltered from east winds by a wood.

c. At St.Agatha (near Cuyk), on sandy soil, sheltered from north winds.

d. At Grave, on sandy soil, extremely sheltered in an orchard.

The four localities are mentioned in the order of an increasing mildness of growth conditions. In each locality two clones (JK3 and JE5) and one mixture of some clones (indicated as M) were planted. JK3 has a particularly poor fruit setting. JE5 and M are, for Jucunda, relatively good in this respect. See fig. 1.

In each locality there were two plots of 100 plants per clone or clone-mixture. One of these plots was always interplanted with the variety Deutsch Evern (every other row), the other one was not.

The interplanting with Deutsch Evern, which has plenty of good pollen, was done to check the possibility of pollen-quality being a factor.

The degree of fruit setting was expressed as the weight of the malformed fruits or nubbins as a percentage of the weight of the whole yield (table 1).

Table 1. Degree of fruit setting in Jucunda clones in different localities, interplanted (+DE) or not (−DE) with the good pollen variety Deutsch Evern. Weight of nubbins as a percentage of weight of total yield

Year	Locality	JK3		JE5		M	
		−DE	+DE	−DE	+DE	−DE	+DE
1952	Middelburg . .	94	60	37	14	26	13
	Woensel . . .	52	40	30	23	39	18
	Average . . .	73 (100)	50 (69)	34 (100)	19 (56)	33 (100)	16 (49)
	St. Agatha . .	very many	few	rather many	few	many	few
	Grave	some	± 0	± 0	± 0	± 0	± 0
1953	Woensel . . .	40	23	26	23	30	15
	Grave	42	15	11	12	20	13
	Average . . .	41 (100)	19 (46)	19 (100)	18 (95)	25 (100)	14 (56)

In 1956 eleven other clones were compared at Rutten in the north-western part of the North-East Polder on very windy, exposed land, and at Wageningen, where the plants were more sheltered. Here the degree of fruit setting was expressed in percentage of nubbins of the total number of fruits (table 2).

From table 1 we see that interplanting with Deutsch Evern clearly the percentage of nubbins reduced in both clones and the clone-mixture. Only clone JE5 did not show a reduction in 1953, apparently because the percentage was on a relatively low level already. Clone JK3 had a very high percentage of nubbins in 1952, which

FIG. 1. a. A GOOD FRUIT SETTING OF CLONE JE5
b. A POOR FRUIT SETTING OF CLONE JK3

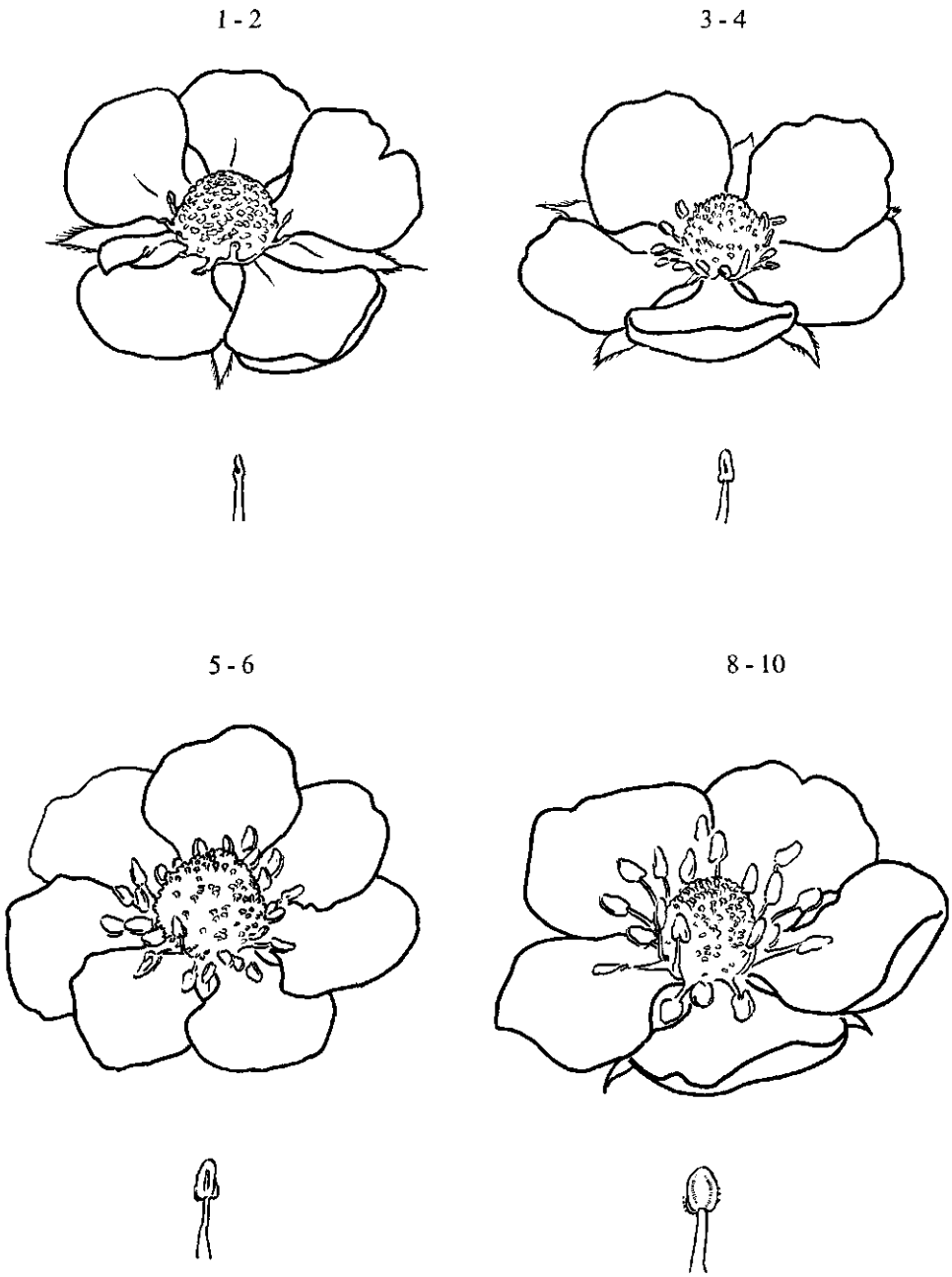

FIG. 2. RATINGS FOR ANTHER-DEVELOPMENT

TABLE 2. DEGREE OF FRUIT SETTING IN JUCUNDA CLONES IN TWO LOCALITIES. NUMBER OF NUBBINS AS A PERCENTAGE OF TOTAL NUMBER OF FRUITS

Clone	Rutten (exposed)	Wageningen (sheltered)
1	24.1	8.6
2	26.2	3.6
3	27.3	5.2
4a	45.9	25.9
4b	70.8	12.7
JK2	26.0	4.7
5	23.1	4.5
6	19.6	5.8
7	26.6	4.5
8	21.2	2.2
9	39.1	4.4
Average . . .	31.8	7.5

percentage was relatively less reduced by interplanting than that of JE5 and M. In the latter interplanting reduced the percentage of nubbins to 56 and 49 % respectively of its value without interplanting, in JK3 it was reduced to 69 % of its no-interplanting value. In 1953, in two localities, the percentage of nubbins in JK3 was lower, though still higher than that of JE5 and M. Interplanting now reduced the percentage of nubbins in JK3 to about the normal degree. These data seem to indicate that the pollen of JK3 is below the normal level of Jucunda. There is also a possibility that the pistils are weaker, because the reduction of the nubbins-percentage by interplanting in 1952 was less than in JE5 and M.

From both tables 1 and 2 we learn that climatological differences may influence the fruit setting in Jucunda. The more a locality was exposed, the more nubbins were produced.

Mild conditions and a more sheltered position resulted in a lower percentage of nubbins. According to table 1 the difference between JK3, JE5 and M is not very great under mild conditions (Grave and St. Agatha). In 1952, in comparison with Grave and St. Agatha, at Woensel the percentage of nubbins of JK3 increased more than that of JE5 and M, and at Middelburg this is still more evident. It seems that JK3 is more sensitive to raw weather than JE5 and M. According to table 2 the clones 4a and 4b have a higher percentage of nubbins at both localities. Evidently, Jucunda in general is sensitive to raw weather, but some clones (JK3, 4a and 4b) are more sensitive than others.

Insufficient pollination in too closely planted beds.

In the south west part of the Netherlands Jucunda is usually grown in rather closely planted beds. As long as the planting material was not too vigorous, this gave satisfactory results, because the flowers projected above the foliage. But after more healthy clones had become available, the plants grew too heavy for the old planting distances;

the flowers were hidden under the heavy mass of foliage, where they apparently were insufficiently pollinated. Very often only at the borders of the beds the fruit setting was good, but not within the beds.

Bees do not improve fruit setting in Jucunda

In cooperation with Dr. A. MINDERHOUD, Wageningen, in 1956 some experiments with bees were made. Bee hives were placed in a trial field of Jucunda. Immediately before flowering, in one part of the field the plants were sprayed with a 10 % sugar solution, in another part of the field they were not sprayed.

The result was that the sprayed plants were visited by a lot of bees and the unsprayed plants were not visited at all. But a difference in fruit setting could not be observed.

It was also tried to use bees for the crossing of different varieties in the breeding work. Several times plants were isolated with bees in an isolation chamber. But in no case was there any result.

Evidently, placing bee hives in Jucunda fields is of no use for the improvement of fruit setting.

3. THE POLLEN QUALITY

In comparison with many other varieties the anthers of Jucunda are usually poorly developed. With an average rating of 10 for the quality of the anthers of Deutsch Evern, the average ratings for the quality of the anthers of 23 Jucunda clones in 1951 were between 5.8 and 7.0. Clone JK3 was rated at 5.8. See also fig. 2.

The result is a low pollen production (also see VAN GILS, 2). However, there does not seem to exist a clear correlation between the quality of the pollen and that of the anthers (see table 3). The quality of the pollen was determined from its morphological appearance under the microscope, in four samples of 100 pollen each per clone.

TABLE 3. THE QUALITY OF THE POLLEN COMPARED WITH THAT OF THE ANTHERS IN 1951 IN 23 JUCUNDA CLONES

Av. rating for anthers	Percentage of morphologically good pollen
7.0	10.2
6.7	9.5
6.6	11.8
6.5	9.7
6.4	11.0, 8.5
6.3	6.2, 9.7
6.2	8.2, 14.3
6.1	8.0, 9.3
6.0	5.0
5.9	6.8, 5.8
5.8	6.2, 7.2, 7.3, 9.5, 9.3

The percentage of morphologically good pollen in JK3 was 9.5 %, which certainly was not the lowest. Clone 413 had the lowest value (5.0 %).

Further observations showed that the percentages of morphologically good pollen may vary with locality, year, and time of the flowering season. Within a week the percentage of morphologically good pollen rose, in one case, from 8.3 to 18.3 %. In another part of the season there were sharp drops, e.g. from 22.7 to 6.3 %. Some other observations are shown in tables 4 and 5.

TABLE 4. INFLUENCE OF LOCALITY AND YEAR ON PERCENTAGE OF MORPHOLOGICALLY GOOD POLLEN

Locality		Wageningen			Heemskerk	
Planted		1950		1951	?	
Year of observation		1950	1951	1951	1950	1951
Bad clone	JK3	15.1	7.7	14.5	10.7	3.0
Good clone	JE5	22.9	11.5	26.0	17.0	7.6
„ „	JK2	22.4	9.7	–	–	–

TABLE 5. PERCENTAGES OF MORPHOLOGICALLY GOOD POLLEN IN GREENHOUSE (UNHEATED) AND OPEN AIR

	Year	Greenhouse	Open air	Average
Bad clone JK3	1950	8.5	15.1	11.8
	1951	10.3	7.7	9.0
	Average	9.4	11.4	
Good clone JK2	1950	14.2	22.4	18.3
	1951	9.9	9.7	9.8
	Average	12.05	16.05	

From all this the conclusion can be drawn that good clones may have a tendency to produce a somewhat higher percentage of morphologically good pollen than bad ones. This may be a factor in the formation of nubbins. But the influence of the growth conditions is so important that nothing definite can be said if the observations are not made under controlled conditions.

A study of meiosis in the anthers of clone JK3 showed nothing out of the common. The pairing of the chromosomes was nearly always complete. Tetravalents and trivalents were not found, and only sporadically some univalents. Where counting was possible, always 28 bivalents were counted. The production of tetrads was normal. Degeneration of young pollen was not observed. Possibly the critical period is about the first pollen mitosis which was not examined.

4. PRELIMINARY PHYTOTRON INVESTIGATIONS ON THE INFLUENCE OF TEMPERATURE

The observations on the percentage of nubbins and on the pollen quality indicate a strong influence of the growth conditions. In order to be able to learn what really

happens, a further study of the phenomena under controlled conditions seems unavoidable. A preliminary step into this direction proved promising already.

As we have seen above there are indications that raw weather may be harmful to fruit setting in Jucunda. Of course this is a combination of several components. In order to start an analysis of this combination we made two experiments on the influence of temperature.

To this end potted 1- and 2-year-old plants of the Jucunda clone JK2, which had passed the winter in a cold frame, were transferred to the growth rooms of the phytotron in spring, shortly before the first flowers opened. They were kept there at different constant temperatures, until the third-order fruits ripened off and were harvested. A clone of the normal-setting variety Deutsch Evern was used as a control. During flowering pollination was carried out daily with a brush, using pollen of plants of the same clone kept at the same temperature. The mature fruits were harvested separately, and of each fruit the degree of setting was scored on a scale of 0–4 (see fig. 3). As the reaction to temperature was the same in the 1-year- and in the 2-year-old plants, the data of both groups at each temperature have been taken together.

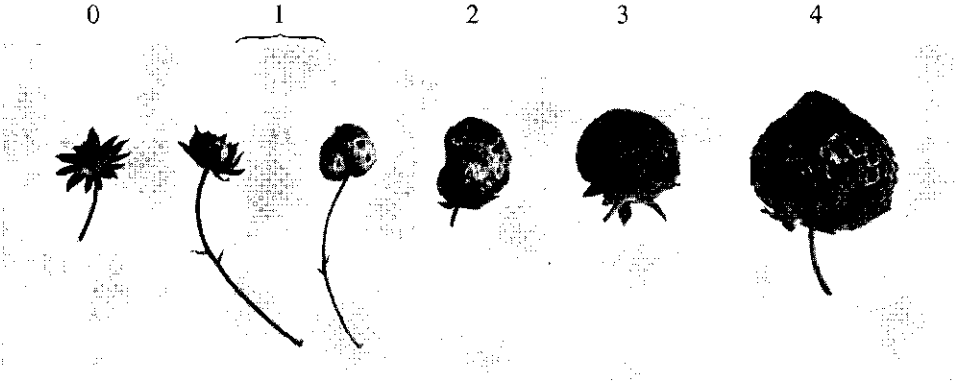

FIG. 3. DIFFERENT DEGREES OF FRUIT SETTING IN JUCUNDA. THE SCORES AS USED IN THIS INVESTIGATION ARE PLACED ABOVE THE FRUITS

The first experiment was made in 1954; it included the temperature range of 17, 20, 23 and 26 °C. The second experiment followed in 1955; it included the temperature range of 10, 12, 14, 17 and 20 °C.

The average scores are presented graphically in fig. 4.

According to the scores at 17 and 20 °C in 1954 and 1955, fruit setting was a little better in 1954. But the difference is small in comparison with the difference shown in 1955 by the scores of the two varieties at 10, 12, and 14 °C.

The scores for fruit setting of Deutsch Evern are about the same for all temperatures. They are between 2.3 and 3.4 over the whole range.

For Jucunda the scores are between 1.6 and 3.0 for the temperature range of 17 to 26 °C, but they drop to zero for the range of 10–14 °C.

So it seems that fruit setting in Jucunda is very sensitive to temperatures of 14 °C and lower.

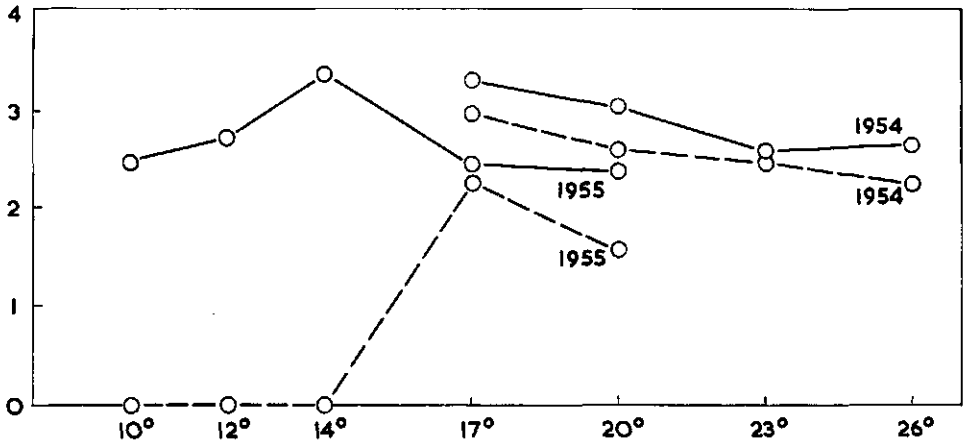

FIG. 4. FRUIT SETTING OF THE VARIETIES DEUTSCH EVERN (———) AND JUCUNDA (- - - -) AT A RANGE OF SEVEN TEMPERATURES, FROM 10 TO 26°C. THE DOTS INDICATE THE AVERAGE SCORES FOR FRUITSETTING (FROM 0 TO 4) AT A CERTAIN TEMPERATURE

SAMENVATTING

Slechte vruchtzetting in aardbeien. II. Misvormde vruchten of "kattenogen" in Jucunda

1. Dit is een verslag van een oriënterend onderzoek naar de oorzaak van onvoldoende vruchtzetting in het aardbeiras Jucunda, speciaal van de kloon JK3.
2. Uit veldproeven werd geconcludeerd:
   a. dat guur weer het percentage 'kattenogen' in Jucunda verhoogt, speciaal in kloon JK3, en
   b. dat tussenplanting met een ras met een goed stuifmeel (Deutsch Evern) het percentage kattenogen kan verlagen.
3. Onvoldoende bestuiving kan ontstaan in het midden van te dichte bedden.
4. Bijen verbeteren de vruchtzetting van Jucunda niet.
5. Gewoonlijk is de ontwikkeling van goede meeldraden in Jucunda niet overvloedig, hetgeen betekent dat de hoeveelheid stuifmeel gering is.
6. De kwaliteit van het stuifmeel (als % morphologisch goede pollenkorrels) van JK3 is soms iets lager dan dat van de goede Jucunda klonen.
7. De reductiedeling in de helmhokjes van JK3 was normaal.
8. De vruchtzetting van Deutsch Evern was goed bij alle temperaturen in de reeks van 10–26°C, terwijl die van Jucunda slechts goed was bij 17–26°C. Bij 14°C of lager vond in Jucunda in het geheel geen vruchtzetting plaats.
9. Daar dit type van onvruchtbaarheid sterk door de groeiomstandigheden van de planten wordt beïnvloed, zal het verdere onderzoek onder gereguleerde omstandigheden plaats vinden.

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