EFFECT OF TEMPERATURE AND LIGHT ON JUNE YELLOWS IN STRAWBERRIES

BY

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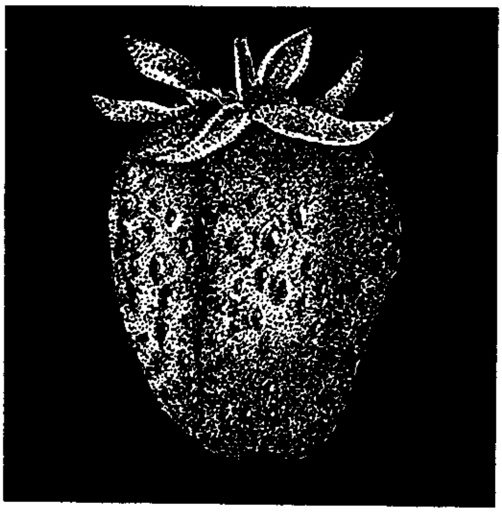

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EFFECT OF SOME ENVIRONMENTAL FACTORS ON THE APPEARANCE OF „JUNE YELLOWS" IN STRAWBERRIES AND ITS SIGNIFICANCE FOR THE DEVELOPMENT OF A TEST METHOD

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INTRODUCTION

"*June Yellows*" or „Voorjaarsbont" as it is called in Dutch, is a disorder of strawberries, which is very well known in the United States and Canada and, in later years, has also been described in Holland (KLINKENBERG, 2), England (REID, 5) and Switzerland (BOVEY, 1). In slightly affected plants it is characterized by an interveinal yellowing of the leaves, in more severe cases it causes mottling or streaking of white and yellow and malformation of the leaves, stunted growth, reduced yield and in the end the plants die.

The symptoms are most prominent during the cool weather of spring. The yellowing practically disappears in summer, but may sometimes return in autumn on a smaller scale. Slightly affected plants, therefore, may look quite normal in late summer, when badly affected plants as a rule can still be identified by the white streaks and distortions of their spring leaves and by their reduced vigour. Some authors distinguish between a mild form of yellows "Transient yellows" and a severe form "Streak" (POSNETTE and CROPLEY, 4).

June Yellows is generally accepted as being non-infective and genetic in origin. The genetically determined disposition to yellows seems to be confined to certain varieties and can be transmitted to their progeny. Symptoms may occur in a variety as early as the first true leaf of the seedling appears, or they may not occur until several years later. A delay of 10–30 years is not uncommon. In case of a delayed manifestation the majority of the plants growing at different localities will become affected at about the same time.

Recovery from June Yellows has never been observed and the runner plants produced by affected plants are also affected. A few years after the appearance of the first symptoms of yellows in a variety, its cultivation becomes unprofitable or even impossible, because healthy plant material is no longer obtainable in sufficient quantity.

This development has been observed in a number of American varieties. In Europe the history of the Scottish variety Auchincruive Climax demonstrates clearly how a disposition to Yellows may remain latent in a variety for years and then suddenly manifest itself on a large scale, causing growers great loss. Further particulars about the disease are given in a recent review of Mc WHIRTER (3).

The summary given above, however, suffices to show that June Yellows constitutes a serious problem both to the breeders and the growers of strawberries. A reliable test method, therefore, would be of great value in the production of new varieties free from yellows and possibly in the control of June Yellows in the existing, susceptible varieties.

The experiments reported below were undertaken with a view to studying the possibilities for the development of such a test method.

To provide a starting-point for our research we have summarized the available information on June Yellows in the form of the following working-hypothesis:

1. Certain strawberry varieties possess a disposition to June Yellows. It is determined genetically in a manner not yet clearly understood.
2. The disposition may remain latent for some time and in this latent condition ("inactive yellows") it cannot manifest itself by yellows symptoms.
3. Sooner or later, however, the latent condition is converted into an active condition ("active yellows") in the majority of the plants at about the same time.
4. The condition of active yellows can only manifest itself ("visible active yellows") under certain conditions (cool spring weather). If these conditions are unfavourable (summer season), no symptoms can be produced ("invisible active yellows").

If the test method is to be effective, it should not only transform the latent disposition into an active condition, but also provide the right conditions for the production of symptoms.

Although in the literature on June Yellows some facts are given indicating that the conversion of inactive into active yellows may be influenced by the growing conditions, this part of the test cannot be developed until further information on this point is available.

The prospects of producing symptoms artificially in plants with active yellows are more favourable. The fact that symptoms of June Yellows have only been observed in spring and autumn suggests that one or more climatic factors play a part here.

In order to discover such factors we started a series of experiments in the spring of 1954, in the expectation that the information thus obtained would enable us to produce symptoms artificially in plants carrying the yellows-complex in an active condition.

MATERIAL AND METHODS

The planning of our experiments was facilitated appreciably by information received from Professor Dr E. C. WASSINK and Miss H. G. KRONENBERG (6) on the behaviour of yellow plants of the variety Mme Moutot under controlled conditions.

In the spring of 1951 Prof. WASSINK succeeded in maintaining, for an indefinite time, the symptoms of June Yellows by transferring plants, which had produced the symptoms in the field, to a temperature-controlled room in the Laboratory of Plant Physiological Research at Wageningen. In this room a constant temperature of 5 °C was maintained and the plants were given continuous artificial light of 4.000 lux by means of Philips fluorescent tubes. At a temperature of 10 °C the yellows symptoms disappeared gradually. Plants of a normal clone remained green both at 5° and 10 °C.

Working on the above data we have in the first instance investigated if the method which proved so effective in maintaining visible active yellows, could also be used for the conversion of invisible active yellows into visible active yellows, i.e. for the production of symptoms in plants which seem normal in appearance.

The experiments were carried out in air-conditioned rooms and glasshouses in the phytotron of our Institute. Here constant temperatures can be maintained automatically; the maximum deviation from the mean temperature is 0.5 °C in the experimental rooms and 1.5 °C in the glasshouses. Only on exceptionally hot days rises the temperature in the 20° glasshouse to 25 °C in the middle of the day. In the experimental rooms the relative humidity of the air varies between 75% and 90%, in the glasshouses the air humidity is kept automatically at 70 % with a maximum deviation of 10 %.

Artificial light in the experimental rooms is provided by illumination-sets consisting of equal numbers of Philips high-tension mercury lamps, type HO 2000, of 450 Watt each, and of frosted Philips incandescent bulbs of 150 Watt each. Before reaching the plants the light passes through a 2 cm layer of water and a glass pane of 1 cm. In this manner the greater part both of the ultra-violet and of the infra-red radiation is absorbed.

In our tests in the experimental rooms the strawberry plants received artificial light of an intensity of 7000 lux, corresponding with 200 milliwatt/sq. cm for the visible radiation between the wave lengths of 4100 and 7200 Å. Light intensity was measured by a Dr Lange photometer, standard type nr. 203/11, calibrated for both lamp types in Luxes and in milliwatts/sq. cm. The data for the energy radiation given above were in close agreement with the results of thermopile measurements carried out by the Landbouw Physisch-Technische Dienst (Physico-Technical Service for Agriculture) at Wageningen.

Plants belonging to six sub-clones of the variety Auchincruive Climax were used as test material in the majority of the experiments. Five sub-clones were produced in Holland from material imported from Great Britain several years ago. The sixth (our stocknumber 774) was a virus-free sub-clone obtained in 1955 from East Malling Research Station. In some experiments a sub-clone of the American variety Blakemore was also tested.

Young runner plants were potted in 1953 and remained in a cold frame until May 1954 when the experiments were started.

YELLOWS PRODUCED ARTIFICIALLY

In the first experiment plants of six Climax sub-clones were taken out of the cold frame on May 15, and placed in an air-conditioned room where they received continuous artificial light at a constant temperature of 5 °C. Under these conditions the strawberry plants continued to grow at a slow rate.

Some plants of sub-clone 774 had already produced yellow leaves in the cold frame. During the experiment the leaves remained yellow and the new leaves formed by these plants also showed distinct symptoms of June Yellows. This is in full agreement with the findings of Professor WASSINK mentioned above.

At first the remaining plants were quite normal in appearance. In the course of the experiment, however, several of them showed yellows symptoms on the young, expanding leaves. The symptoms remained also visible on the full-grown leaves, and plants with Transient Yellows could be easily distinguished from those with Streak.

After ten weeks, when there was no further increase in the number of yellow plants, the affected plants were counted.

The results of this experiment show clearly that under the conditions mentioned, symptoms of June Yellows can be produced in apparently normal plants of the Climax variety, or to put it in the terms of our hypothesis: in a number of test plants invisible active yellows was transformed into visible active yellows under the conditions of the experiment. The data given in Table 1 demonstrate that there is an appreciable variation both in the extent and in the degree of yellows obtained in the different sub-clones.

TABLE 1. JUNE YELLOWS ARTIFICIALLY PRODUCED UNDER CONTINUOUS ILLUMINATION AT 5 °C

Sub-clone	Nr. 774	Nr. 876	Nr. 877	Nr. 878	Nr. 879	Nr. 880
Total number of plants	15	16	14	15	14	15
Number of affected plants	15	5	2	1	0	2
Nature of the symptoms	Streak	Transient Yellows	Transient Yellows	Transient Yellows	—	Transient Yellows

EFFECT OF VARIATION IN TEMPERATURE AND ILLUMINATION

The object of the next experiment was to ascertain if a constant temperature and a continuous illumination are essential for the production of symptoms.

To this end plants from six Climax sub-clones and from one Blakemore sub-clone were divided into four comparable groups. Three groups were kept at a constant temperature of 5 °C and illuminated for 24, 18 and 12 hours per daily cycle respectively. The fourth group was illuminated for 12 hours, but the temperature was 8.5 °C in the light period and 1.5 °C in the dark period. After ten weeks the plants with symptoms of yellows were counted in each group.

The experimental results shown in Table 2 indicate that the number of yellow plants is affected neither by a shortening of the daily photoperiod nor by a fluctuation in the temperature around a mean of 5 °C.

TABLE 2. INCIDENCE OF YELLOWS AT DIFFERENT PHOTOPERIODS, BOTH AT A CONSTANT AND AT A MEAN TEMPERATURE OF 5 °C

Daily period of illumination .		24 h	18 h	12 h	12 h
Temperature .	Light period	5 °C	5 °C	5 °C	8.5 °C
	Dark period	5 °C	5 °C	5 °C	1.5 °C
Number of plants tested . .		31	30	30	30
Number of affected plants . .		5	5	4	5

This is of importance in view of an application of the test on a practical scale in a glasshouse in winter, because the necessity for a strict maintenance of a constant temperature and a prolongation of the short winter day by artificial illumination to a 24 hour day would be a drawback then.

Some observations have also been made on the behaviour of yellow plants at temperatures above 5 °C. To this end plants which had produced symptoms in the experimental rooms were kept in glasshouse compartments at constant temperatures of 10 °C, 17 °C and 20 °C respectively. At the three temperature levels the yellow colour of the full-grown leaves turned into green within 2–3 weeks. After a month the colour of the newly formed leaves was green too. At this stage the plants with Transient Yellows could not be distinguished from normal ones; plants with Streak could still be recognized by the white streaks and the distortions of the older leaves, and by their stunted appearance.

At 20 °C the plants with Streak recovered quickly. After three months they had completely regained their vigour. That there was no actual recovery became evident when severe symptoms reappeared after a renewed treatment of the plants at 5 °C.

EFFECT OF PRE-TREATMENT

A comparison of the results from different tests revealed the existence of some kind of relationship between the time required for the production of the first yellows symptoms and the temperature conditions of the period preceding the test. This relationship was clearly demonstrated when the results obtained with plants which had received a "cold" pre-treatment were compared with those obtained with plants which had received a "hot" pre-treatment.

The graph of Fig. 1 shows the percentage of affected plants observed at different times after the beginning of the test, both in a group of plants which had received a cold pre-treatment (cold group) and in a group of plants which had received a hot pre-treatment (hot group). During the pre-treatment period of 2–3 months the plants of the cold group had been kept either in a cold frame in early spring or in an air-conditioned room at 5 °C with continuous artificial light; the plants of the hot group had received a pre-treatment of the same duration in a glasshouse at 20 °C between 19 May and 20 September.

In both groups five sub-clones of the Climax variety were represented in the same

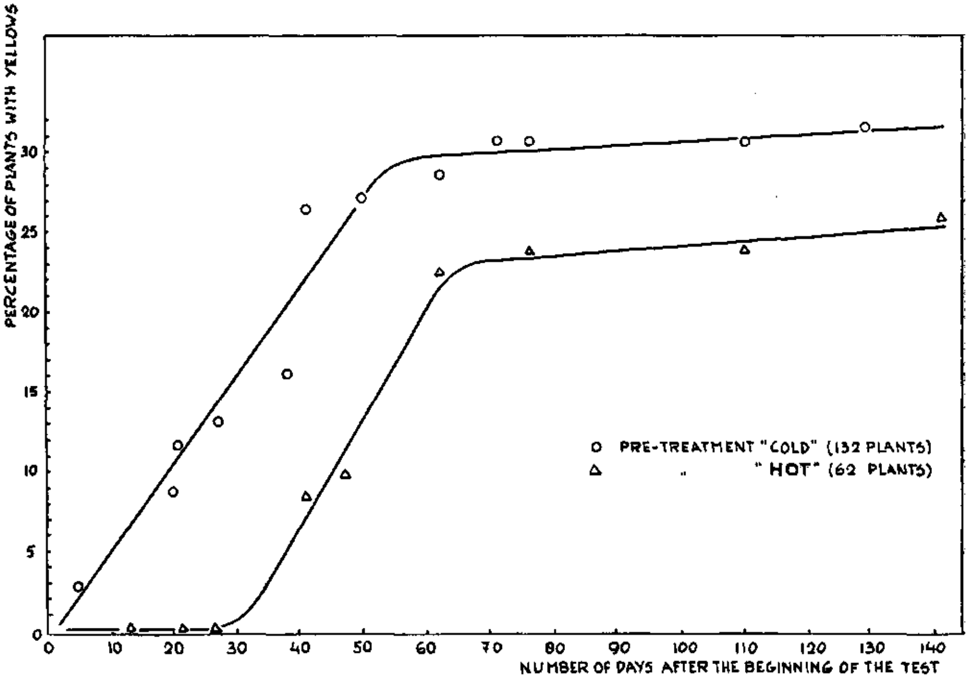

FIG. 1. PERCENTAGE OF AFFECTED PLANTS OBSERVED AT DIFFERENT TIMES AFTER THE BEGINNING OF THE TEST

ratio. Plants were not classified as affected until they had shown symptoms on young leaves formed after the beginning of the test.

When studying the graph of Figure 1. three phenomena attract our attention:

1. Whereas in the cold group the first symptoms appear immediately after the beginning of the test, in the hot group this does not happen until after about a month.

As in the hot group the plants usually produce one or more normal leaves before the first yellow leaf appears, an initial check in growth cannot be the cause of this delayed reaction. Possibly initiation of the symptoms occurs in a very early stage of development of the leaves. If this is true, in the hot group some time is required before the leaf primordia have developed into young leaves and symptoms are shown; in the cold group the symptoms are already present in the young folded leaflets and become visible as soon as these leaflets unfold.

Consequently tests on plants from an environment with a high temperature should be continued about a month longer than those on plants from a cool environment.

2. After the appearance of the first symptoms in both groups the percentage of affected plants increases at about the same rate until a certain maximum is reached. After this moment hardly any increase can be observed.

These observations agree very well with the conception of our working-hypothesis. According to this hypothesis, a variety, after having shown the first symptoms, will consist partly of plants with inactive yellows and partly of plants with active yellows; the latter plants producing symptoms as soon as favourable conditions are provided.

A test, therefore, need not be continued beyond the moment at which the initial increase in the percentage of affected plants has come to a standstill.

3. In the hot group the maximum percentage of affected plants is four-fifths of that in the cold group.

There is a possibility that this difference is caused by a conversion of active yellows into inactive yellows during the hot pre-treatment and/or by the reverse process during the cold pre-treatment. Further experiments are needed to clear up this highly interesting point.

Discussion

The experiments reported above have proved that the artificial production of June Yellows in the varieties Auchincruive Climax and Blakemore can be achieved by keeping plants at a mean temperature of 5 °C and giving them an artificial illumination with an intensity of 7000 Lux for 12 hours a day. They have also shown that under these conditions probably all plants carrying yellows in an active condition will produce symptoms.

We, therefore, feel justified to say that this treatment may provide a useful basis for the development of a practical method for the detection of plants with active yellows. In developing and applying such a method due attention should be paid to the possible effect of temperature conditions during the period preceding the test. Another point of importance is that in testing strawberry plants in autumn more time will be required, because a breaking of the condition of winter dormancy by a low temperature treatment must be effected before the plants can react.

When assessing the practical value of the test method, it should be borne in mind, however, that by this method it will be possible to eliminate only plants with active yellows. It may be useful in the reduction of June Yellows, but will not be effective in eliminating or preventing this disorder. This can only be achieved if we succeed in developing a method by which conversion of inactive yellows into active yellows can also be effected.

For further research into the possibility of such artificial conversion a test method for active yellows is indispensable. In addition to its value in restricting the disorder in existing susceptible varieties, the test method proposed is of vital importance in developing an allround test on June Yellows.

Summary

The symptoms of June Yellows in strawberries only appear in spring and autumn, and vary in extent from year to year. In order to find a test method for June Yellows which would make it possible to produce yellows symptoms independently of the weather conditions, an investigation of the climatic factors favouring the appearance of yellows was started.

It proved possible to produce in apparently normal plants of the varieties Auchincruive and Blakemore symptoms of both "Transient Yellows" and "Streak" by growing them at 5 °C and providing artificial light of about 7000 lux for at least 12 hours per day.

For plants from an environment with a relatively low temperature a treatment of about two months proved sufficient to produce a maximum effect. For plants from an environment with a relatively high temperature a treatment of about three months was necessary to obtain a maximum reaction.

SAMENVATTING

Invloed van enige klimaatsfactoren op het optreden van voorjaarsbont bij aardbeien en de betekenis daarvan voor de ontwikkeling van een toetsmethode

De symptomen van voorjaarsbont bij aardbeien treden uitsluitend op in het voorjaar en najaar, maar in verschillende jaren in verschillende mate. Teneinde de beschikking te krijgen over een toetsmethode op Voorjaarsbont, waarbij onafhankelijk van toevallige weersomstandigheden bontsymptomen kunstmatig geproduceerd kunnen worden, is een onderzoek ingesteld naar klimaatsfactoren welke het optreden van bont begunstigen.

Het bleek mogelijk om bij uiterlijk normale planten van de rassen Auchincruive Climax en Blakemore symptomen zowel van „Transient Yellows" als van "Streak" te voorschijn te roepen door ze te plaatsen in een omgeving met een temperatuur van 5 °C en een belichting van ± 7000 lux gedurende minstens 12 uren per etmaal. Voor planten afkomstig uit een koude omgeving bleek een behandeling van ongeveer twee maanden voldoende te zijn om een maximaal effect te bereiken, bij planten uit een warme omgeving was voor een maximale reactie een behandeling van ongeveer drie maanden nodig.

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PERSBERICHTEN UITSLAGEN PRACTIJKPROEVEN

Zijn geplaatst in diverse tuinbouwbladen:

18- 1-'50.	Uitslag Practijkproeven Tomaten 1948–1949.
10- 3-'50.	Uitslag Practijkproeven Wortel Berlikumer 1949.
4-10-'50.	Uitslag Practijkproeven Tuinbonen 1949–1950.
29-11-'50.	Uitslag Practijkproeven Bak- en Zomerwortelen 1949–1950.
29-11-'50.	Uitslag Practijkproeven Platronde en Ronde Kroten 1949–1950.
12-12-'50.	Uitslag Practijkproeven Pronkbonen 1950.
21- 3-'51.	Uitslag Practijkproeven Westlandse Boerenkool 1949–1950.
3- 9-'51.	Uitslag Practijkproeven Spitskool 1950–1951.
7-12-'51.	Uitslag Practijkproeven Flakkeese Winterwortel 1950–1951.
23- 1-'52.	Uitslag Practijkproeven Vroege en Herfst Rodekool 1950–1951.
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Jaarverslag 1950. 1 (1951) . . . . Uitverkocht

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De publicaties, waarvan prijs èn uitgever worden vermeld zijn verkrijgbaar in de boekhandel. Overigens wende men zich tot de opgegeven bronnen of tot de Bibliotheek van het I.V.T.

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[1]) Zolang de voorraad strekt kunnen deze publicaties franco worden toegezonden, na ontvangst van het vermelde bedrag op giro no. 425340 van het Instituut voor de Veredeling van Tuinbouwgewassen, S. L. Mansholtlaan 15 te Wageningen onder vermelding van wat verlangd wordt; ook bestaat de mogelijkheid deze publicaties uit de bibliotheek van het I.V.T. te lenen.

[2]) Eerder verschenen publicaties zijn vermeld achterin in de Mededelingen nos 1 t/m 65 en in de jaarverslagen van het I.V.T.

ERRATA

De prijs van de hiernaast vermelde Achtste Rassenlijst voor Groentegewassen bedraagt f 1.75.
In plaats van 1955 leze men 1956.