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THE INFLUENCE OF DIFFERENT TEMPERATURES ON DEVELOPMENT GROWTH AND FLOWERING OF HYACINTHS, TULIPS AND DAFFODILS

BY

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L'influence des différentes températures sur le développement et la floraison des jacinthes, tulipes et narcisses.

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The influence of different temperatures on development, growth and flowering of hyacinths, tulips and daffodils[1].

By

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Mit 21 Textabbildungen.

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When I received the invitation to give a lecture on our researches about the influence of different temperatures on development, growth and flowering of flowerbulbs before this distinguished audience I hesitated before accepting this honour.

This was due to the fact that nobody knows better and even can know better than we do ourselves, even after we have been able to obtain some practical results, how relatively poor and unsatisfactory our knowledge is of the vital problemena that occur in our plants.

Because we are working among our plants in the very centre of so specialised a culture as our flowerbulb-culture is, we are in so close a contact with its difficulties, that we can fully obtain a judgement about the complexity of its problems. With every slight progress we realize only too well how much is still to be solved.

This placing of our laboratory in the centre of the bulb-culture does not only give us the necessary contact with, the correct insight in its problems, needed for the research work itself, as well as for the correct interpretation of its results, but it also prevents us from overrating the results of our own experiments.

At the same time we have in this way a direct contact with the intelligent growers. They speak a different language, don't work with microscope or accurate balances, but they have a knowledge of the lifeconditions of their plants, which commands our highest respect. They have often been able to solve very difficult problems, before official science was aware of their existence.

A common experience is that the precocity of the flowering of all bulbs, ceteris paribus, largely depends on the climate in which they have been grown. If they have ripened early, we may expect an earlier flowering from them than from other bulbs that have been grown in a later climate. For example under normal conditions bulbs from the South of France will flower earlier in Holland than bulbs that have been grown in Holland.

[1] Invitation Paper read before the combined sections of Physiology and Agronomy at the VI. International Botanical Congres at Amsterdam. Sept. 1935.

It was the ingenious idea of the Dutch bulbgrower *Dames*, about 30 years ago, to master the difficulty of the early-forcing of hyacinths by giving them during the time of ripening, instead of the whims of the natural climate, an artificial climate, more suited to the conditions that are favourable for the early-flowering capacities for the next season.

For this purpose he lifted the bulbs about 4 or 5 weeks earlier than normally and brought them into a bulbhouse, where they were stored at a temperature of about 85° F. for some weeks. The foliage of the hyacinths was still green, when they were lifted and had to be cut. The ripening of the bulbs took place under artificial conditions. At this time the development of the foliage for the next season had already begun, but the development of the flower under normal conditions in the field only begins a few weeks later. It now proved to be possible to stimulate the first development of the flower by storage at a higher temperature indoors. The development of the new leaves stops and the bulb begins with the formation of the flower. By a large number of experiments, it was possible, to study the optimal temperatures for the formation and further development of the flower and so the preparing-method of hyacinths for early-forcing was found. He, indeed for the greater part solved the problem of the preparing of hyacinths; most varieties nowadays bloom about three weeks earlier than before and the prepared hyacinths have become favourite Christmasflowers.

By lengthening the period of demand for his product in this way, he already 30 years ago got results, which are now pursued by the investigators who have introduced Jarovisation or Vernalisation into agriculture.

His work laid the fundations of all work done later on by all other workers on the early-forcing of flowerbulbs.

For this bulbgrower, who, though he had not received an education at the University, was a scientist of the highest order, Dutch bulbgrowers have erected a Monument, and I consider it a great honour that it was placed in front of our laboratory (fig. 1).

When I give a short survey here of a part of the work, my cooperators and I have done in our laboratory and its surrounding fields, I shall have to stress many blanks in our knowledge about our problems that have still to be filled up.

I think that, on the last morning of this Congress, where so many able men have told us about the results of their efforts, it will not be amiss to emphasize that many problems cannot be solved by Laboratory research-work only.

The biologist who is studying wild plants, knows, that he has to pay due attention to the natural surroundings of his objects and the research worker, who has to deal with cultivated plants, has to keep in mind that for him, these natural surroundings are only limited by the highest demands the ultimate consumer may ask from his products.

I am glad to have here an audience of the combined sections of Physiologists and Agronomists, the last group of which will certainly be able to understand our difficulties from their own experience better.

This does not imply any essential difference between the so-called "pure" and "applied" Botany as far as concerns the valuation of the scientific standing of the work. Neither in the necessary accuracy of the observations nor in the methods of research there is any essential difference whatsoever, except in the object they are studying.

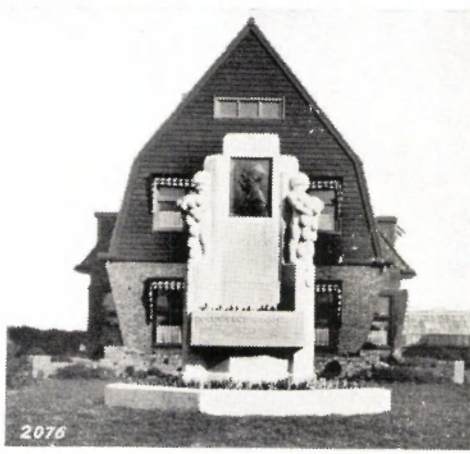

Fig. 1. Statue of Nicolaas Dames, the pioneer of modern flower-bulb culture at Lisse.

The burden of the complexity of their problems, however, weighs much heavier upon the worker in the domain of applied science.

Theoretically it is not so difficult to prescribe or even dictate the necessity of subdevising the complex activities that constitute the life of a plant into its separate functions, to establish the rôle of each of these in the general behaviour of the organism and finally to analyse, as thoroughly as possible, every process into its simpler constituting parts, as *Maximow* expressed it so well in the introduction of his textbook of plant-physiology.

We certainly do know that and we do work along this line. In practice however we really have to deal with problems that are connected with the morphology, anatomy, physiology, practically all other branches of our biological Science, among them plant-pathology.

In his text-book of plant-physiology *Maximow* does not mention Plant-pathology as one of the branches of Botanical Science connected with physiology. I agree with him and take it for granted that plant-pathology, connected just the same with all the branches claimed to be indispensable for plant-physiology, practically is nothing else than plant-physiology.

We have begun our work on the influence of different temperatures on the flower-bulbs in connection with the combating of some diseases.

Our purpose was to kill the parasites inside the bulbs. It is obvious that the remedy was not allowed to be worse than the complaint and it was preferable that the bulbs at least survived the treatment.

The only desinfectant that proved to be of any use was a high temperature; only in this way could we penetrate to the centre of the bulbs; killing the parasites without destroying the bulbs themselves.

In this way we succeeded in combating the nematode diseases by means of a hot-water treatment and the yellow-disease of Hyacinths by a hot-air treatment.

I shall not go into the details of those researches and even neglect here the direct influence of the treatment on the parasites or the diseased bulbs. Because we however cannot recognize the diseased bulbs from the outside, we are obliged to treat our whole stock, the diseased bulbs and the sound ones together. The demands of an economic culture make it necessary to treat the stock even when no more than $1^0/_{00}$ is attacked by the disease and for this reason the influence of the treatment on the sound bulbs is of paramount importance.

Not only the growth of the healthy bulbs might not be unfavourably affected, but, as our bulbs are grown and used for their flowers, also the influence on the flowering results had to be studied.

It is quite impossible for me to give you in a few minutes sufficient insight into the complexity of the problems we had to solve.

It must be clear however, that we had to study ourselves all the factors that influence the process of development, growth and flowering of the healthy bulbs in the first place before we could expect any success from methods of curing the infected stocks in this way.

Now again, every process had to be analysed into its simpler constituent parts—"the role of each of these in the general behaviour of the organism had to be established" and "from the study of the separate functions that constitute the life of the plant we had to come to an understanding of the complex activities that occur in the plants".

Our botanical science has grown to such an extent that one cannot know the ropes of every branch of our Science. But even when this was possible, how often do we find what we need in the scientific literature.

I only will quote here *van Iterson,* who in the "Went-number" of the "Vakblad voor Biologen" said: often pure science did not yet study the problem needed for applied science, or studied it insufficiently.

At the same time applied science can be of some help for the pure scientist for the interpretation of the results attained with their experiments. I may mention here the work done in our Laboratory (Public. No. 39) by *Dolk* on the respiration of Hyacinths! He was able to give a very simple explication of the increase of respiration after a hot-waterbath of bulbs, potatoes, and others by proving that this was only due to bacterical-action, as *Kuyper* has found to be the case with his experiments on the respiration of peas.

Now we do not need any more the rather hypothetical explanation formerly given of these phenomena.

I hope you will excuse this digression.

I come to our subject now and can tell you, that in studying the factors that influence the process of development, growth and flowering of our bulbs, we found that in most cases not only our methods of combating the diseases, influenced those processes, but that the

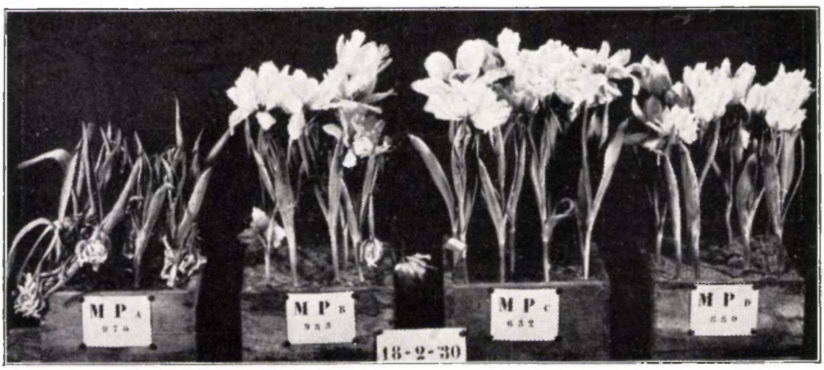

Fig. 2. D. V. T. Murillo. The in the extreme left box (970) is the earliest, but all the flowers "tumbled over" before they were open.

circumstances most favourable for the growth and flowering results of the sound bulbs very often were also most favourable for the spreading of parasitical or physiological diseases.

May we now state to have found the optimal conditions for the growth of our bulbs when those at the same time cannot be applied without a great danger for the crop?

If we leave the parasitical diseases out of discussion here and only discuss the flowering capacity of the bulbs after different treatments, may we speak of optimal treatment for a celerrimal flowering when all or a great percentage of the tulips will "tumble over" owing to this treatment? As Miss *Pinkhoff* found at our Laboratory this disease is connected with a disturbance of the carbo-hydrate-metabolism of the tulips and is strongly promoted by low-temperature storage, applied to improve the capacity for early-forcing (fig. 2).

But even we should not only take into account the physiological diseases. We have also seen that the "quality" of the flower, its size, colour, strength of the stalk, are greatly dependent on the previous

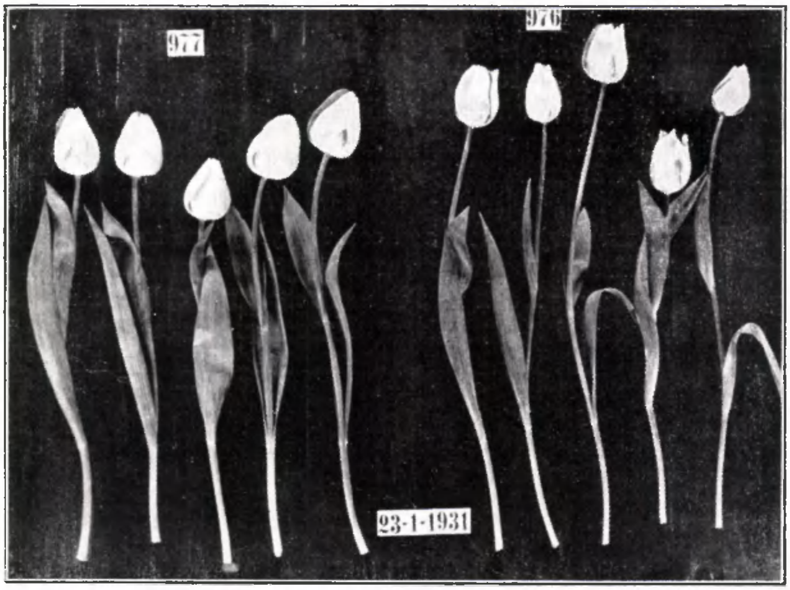

Fig. 3. Darwin tulip William Copland. The flowers loose in "quality", dwarfing of the flowers, stem too long and too weak (976) by "optimal" treatment for "celerrimal" flowering. No. 977 shows the result of a "better" treatment, by which the tulips flower just a little later.

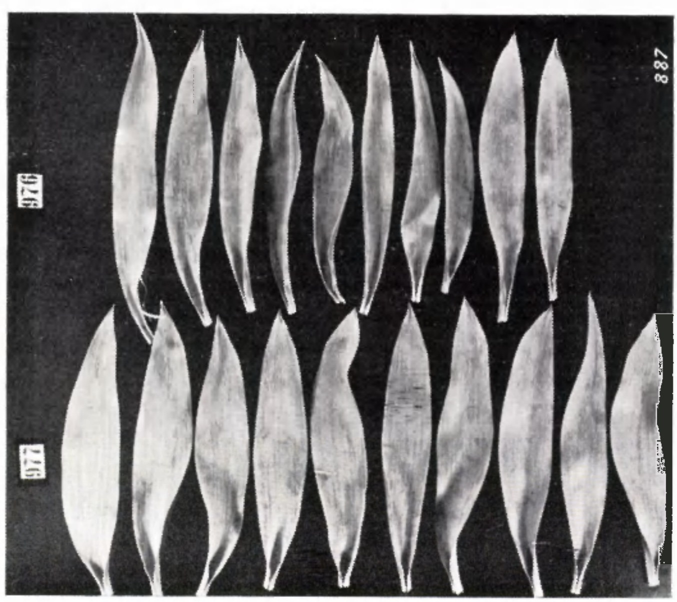

Fig. 4. The size of the foliages of the tulips of fig. 3 demonstrate still more distinctly the influence of treatment on the vigour or the quality of the plants.

treatment received by the bulbs. Very important for the "quality" of the flower of the tulips for instance is the stage of development at which they are brought to the low-temperature storage (9° C.), or the storage conditions after planting of the bulbs.

I ask you to compare the "quality" of the flowers of fig. 3. The difference in quality of the plants is still better to be seen in fig. 4.

This too makes it necessary to find a compromise between the fitness for early-flowering and the "quality" of the flower!

If we state that a certain treatment will give an optimal flowering-result, this requires great prudence and we should for instance consider:

that a special treatment which makes the bulbs fit for *early*-forcing, may be detrimental to *later* use which will become evident from the following example (fig. 5).

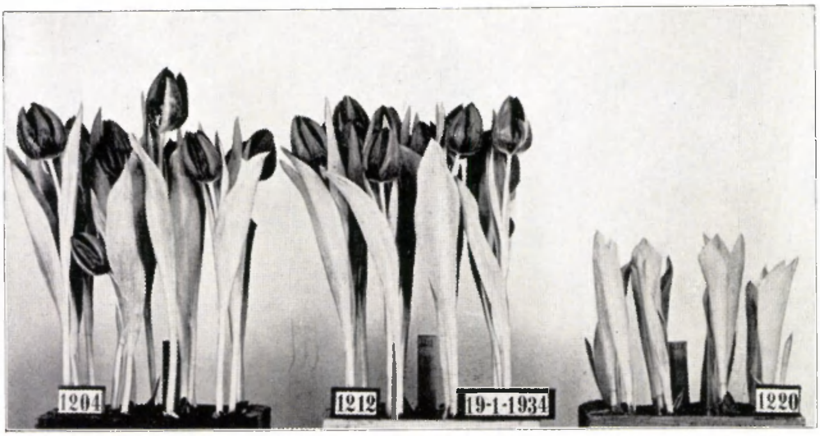

Fig. 5. Early tulip Prince of Austria. With early forcing No. 1204 treated like No. 1214 (fig. 6) is best, and No. 1220, treated like 1226 (fig. 6) is worthless now.

Of 3 boxes E. V. Tulp Prince of Austria the leftmost (1204) was earliest when forced in the beginning of Jan. 1934 (20° C. to stage VI, then 17° C., stored outside).

No. 1212 had had 1 week 30° C. in advance, then 20°C. to stage VI and 17 until being stored outside, whereas No. 1220 had remained at $25^1/_2$°C. to stage VI, then at 20°C. until being stored outside.

The last box (1220) failed in early-forcing (fig. 6).

In March, however No. 1214, which had been treated similarly to 1204 became much too long and limp and was therefore useless, whereas No. 1226 (treated like 1220) was now the best by far.

Dr. *Beijer* has also shown that a high temperature in the beginning during storage in the bulbshed, immediately after lifting, which may be necessary for fighting a disease or may be optimal for clerrimal flowering, reduces the number of flowers of the cluster of the hyacinths, to such a degree that it considerably loses in value (fig. 7).

This part of his investigations, about which he has already told something to the visitors of the Laboratory for Bulbresearch last Wednesday, will soon be published separately.

So always health, fitness for early-flowering as well as the quality of the flower are equally concerned and these make different demands for treatment.

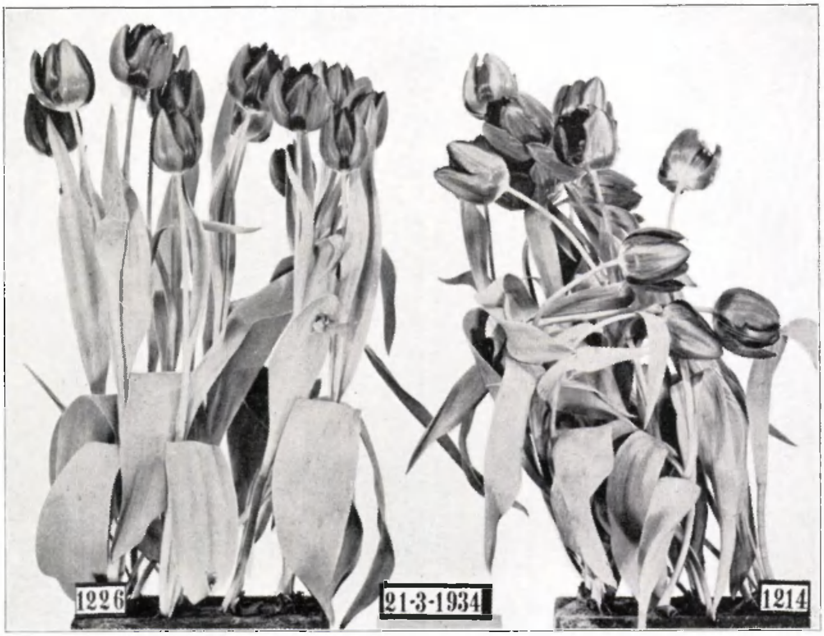

Fig. 6. Early tulip Prince of Austria. With a later forcing date No. 1226 treated like No. 1220 (fig. 5) is best and No. 1214, treated like No. 1204 (fig. 5) is worthless now.

I believe, that by our work we have been able to contribute something to the improvement in flowering-results obtained with our bulbs of late years. At the same time I want to draw your attention to what *Blaauw* c. s. have done and especially to the way in which they have studied the formation and the morphological development of the flowers, enumerated the different stadia and studied the influence of different temperatures on the morphological symptoms.

In behalf of the "quality" of the flowers in normal cases we do not want to give an after-treatment at a lower temperature than 17 °C. for Hyacinths. We gladly loose just a little of the precocity in exchange for a much better quality of the flowers.

With Tulips it was more difficult to get results with the ordinary method of preparing applied by Dames for Hyacinths. Here the difficulty arises that the Tulip cannot be induced to start the formation of the flower by artificial conditions, but first finishes about the normal number of leaves. The progress with the precocity of the flowers of the Tulips is caused chiefly by storage-temperatures given them after the formation of the flower has begun and their influence on its development.

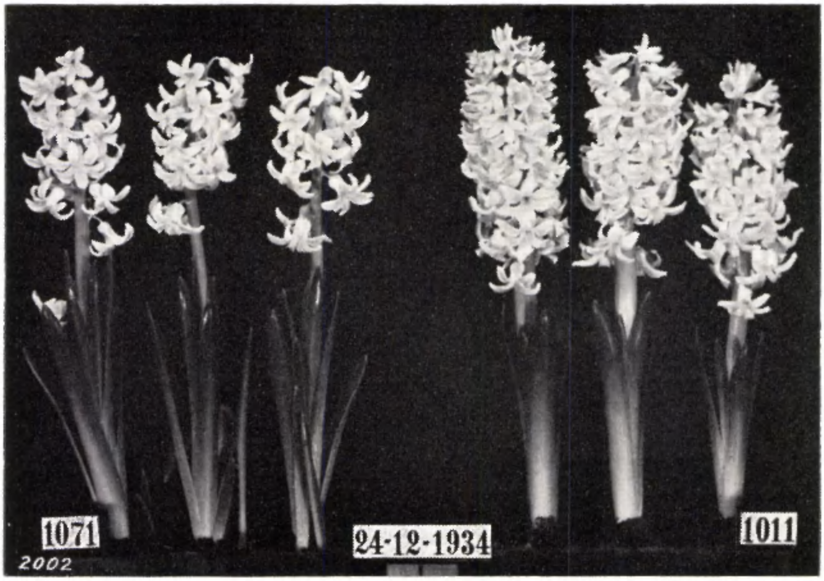

Fig. 7. Hyacinth L'Innocence. A high temperature immediately after lifting for preparing of hyacinths unfavourable influences the number of flowers of the cluster.

No. 1071: beginning temperature 35° C. (95° F.), average number of flowers per cluster 17. No. 1011: beginning temperature 20° C. (68° F.) average number of flowers per cluster 40.

That similar results were not immediately obtained with Daffodils must be ascribed to the fact, that the development of the flower for the next season in our climate begins in the open field in the beginning of May, whereas the normal time of lifting is about $2^1/_2$ months later, depending on the season and the variety. By this very early starting of the flowerformation of the Daffodil, it becomes still more impossible to influence the beginning of the development of the flower by artificial storing conditions than with the Tulip. For early lifting of the Daffodilbulbs soon leads to excessive dwarfing of the flowers, poor growth, as well as to an increased susceptibility of diseases in the following year.

Fig. 8. Narcis Glory of Sassenheim. Flowering at a very early date, after storage at 48° F.

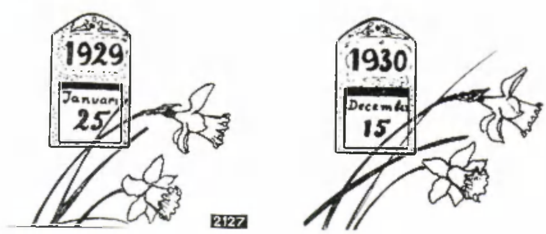

Fig. 9. Progress in precocity of flowering of Daffodils by storage at low-temperature.

Still, after having shown the first result of our experiments on Dec. 30 with a box of Narcissus Glory of Sassenheim (fig. 8) we succeeded in getting many varieties in flower about four to six weeks earlier than used to be possible, by the use of low-temperature storage (fig. 9).

That the accelerating effect of cold-storage is not due to a direct influence of the low temperature on the growing speed of the young plant appears among others from a diagram (made by *Beijer*) which shows that the growth is less at a storage of 9 °C. than e. g. at a temperature of 15 °C.

On Sept. 4th. '29 the shoot inside the bulb of E. V. T. Prins of Austria was more than 23% shorter with bulbs cooled at 9° than with those stored at 15° (fig. 10).

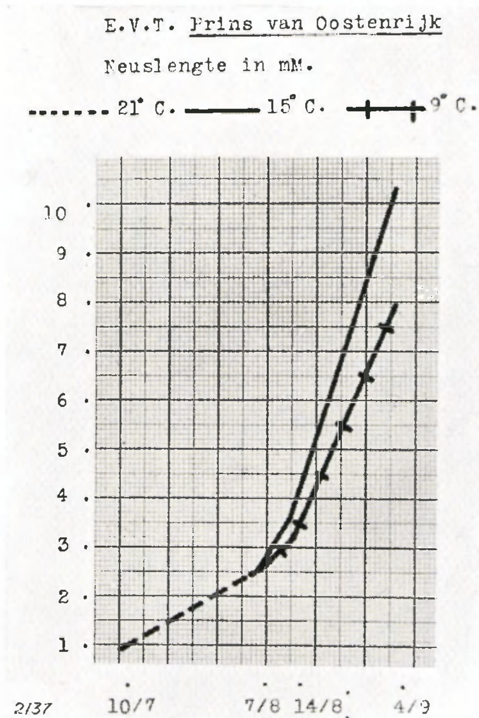

Fig. 10. Growth of the shoot inside the bulb after storage at 15° C. and at 9° C.

Yet the former were in full flower on Jan. 4th. and the latter on Jan. 10th. 1930.

Neither does 9 °C. have immediately a directly accelerating influence on the growth of the flowerbud of Narcissi (fig. 11).

On Oct. 9th. 1931 e. g. the length of the flowerbud of Narcis Talma appeared to have remained shorter at 9° than at 13°.

Yet here too the former flowered no less than a fortnight sooner.

This shows that neither the morphological stage of development nor the size of the flowerbud is always a reliable criterium for the forcing-capacity of the bulb.

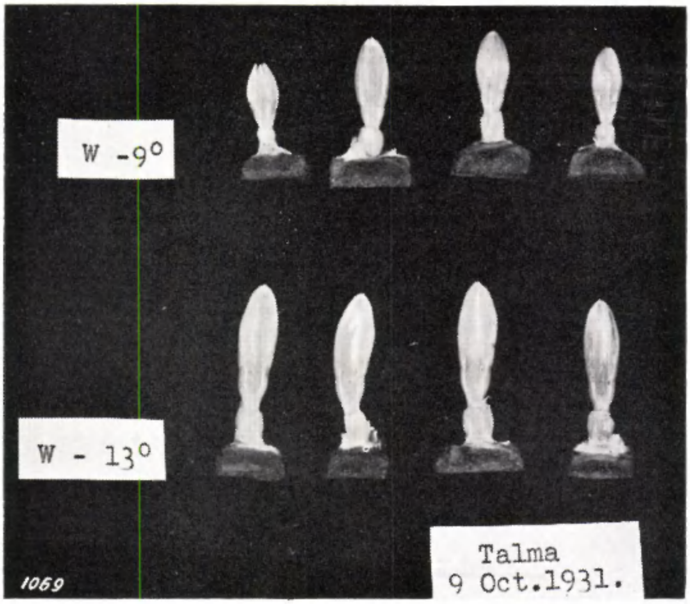

Fig. 11. The flowerbud of Daffodil Minister Talma after storage at 9° C. (48° F.) and at 13° C. (55,5° F.). The former flowered a fortnight earlier.

Fig. 12. Tulip Prince of Austria. Difference in precocity attained by giving a short dose of heat. No. 859: immediately after lifting stored at 40° C. (104° F.) during 24 hours; for the rest same treatment for both lots.

We found among others that a high temperature for example for the tulips at the beginning, soon after lifting can bring about a strong retardation of the growth of the flowerbud and yet has a very favourable influence on the precocity of the flowers in the next season (fig. 12).

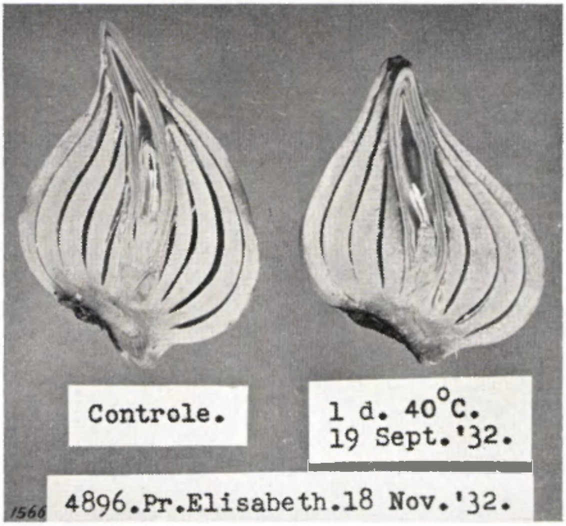

Fig. 13. Damage through experimental heating. Tulip on the right treated for 24 hours at 40° C.

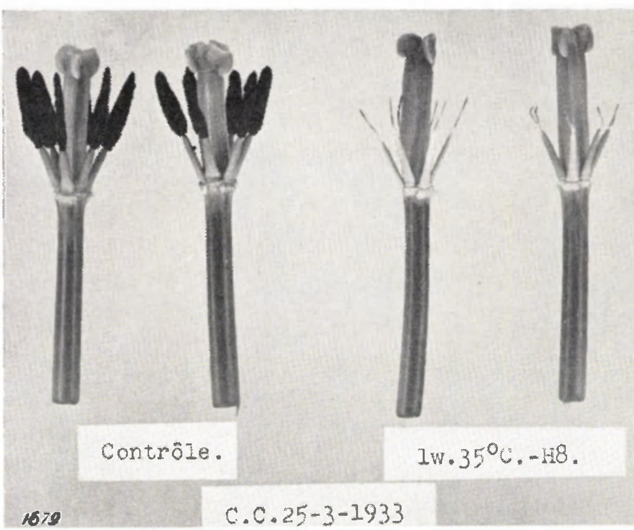

Fig. 14. Tulip Couleur Cardinal from fig. 15: on the right anthers destroyed by heating.

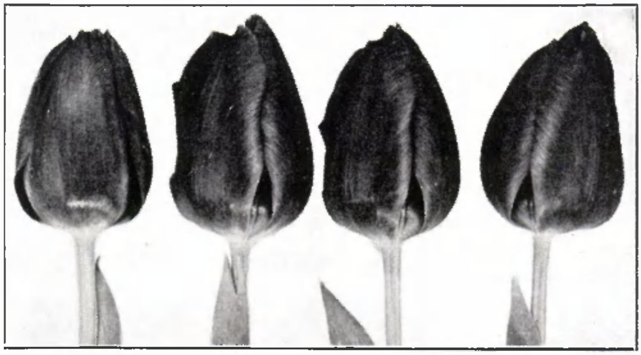

Fig. 15. Normal flowers of Tulip Fred Moore.

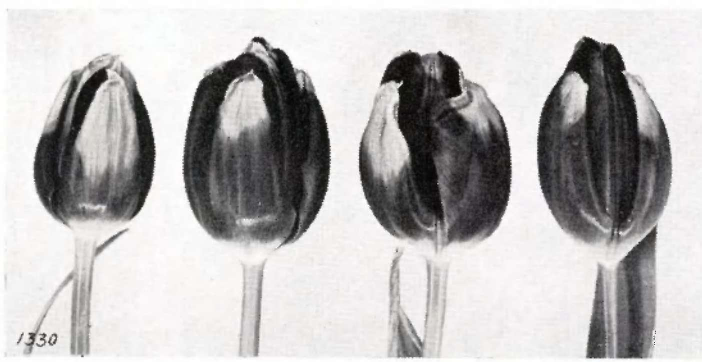

Fig. 16. Tulip Fred Moore: Flowers slightly damaged after storage at too high a temperature.

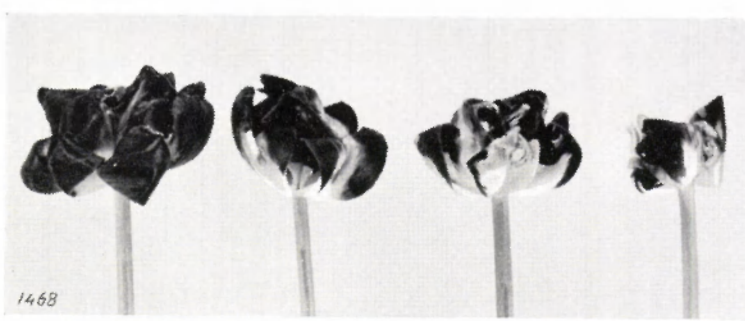

Fig. 17. Tulip Fred Moore: Flowers crippled through heating.

For this reason it seemed necessary for us to study the biochemical processes that take place in the bulbs under different storing conditions and also the connection between these biochemical processes—the morphological development and the respiration of the bulbs.

Dr. *Algera* is continuing these researches and I hope he shall soon be able to give a preliminary report of his work, that, I am sure, also will be of some interest for the pure-scientists.

Fig. 18. Tulip Wm. Copland: Different stages of plant-deformation after heating in transit.

However, if we have succeeded in finding the best treatment for growth in the field and in fixing with certainty the best method of the preparation for early-forcing, even then we are not yet ready with our problem (fig. 13—18).

Very often we have seen that a short spell of hot-weather during the shipping of the bulbs, or even 1 à 2 weeks of a temperature of 25°C. to 30°C., not only spoiled their fitness for early-forcing, but

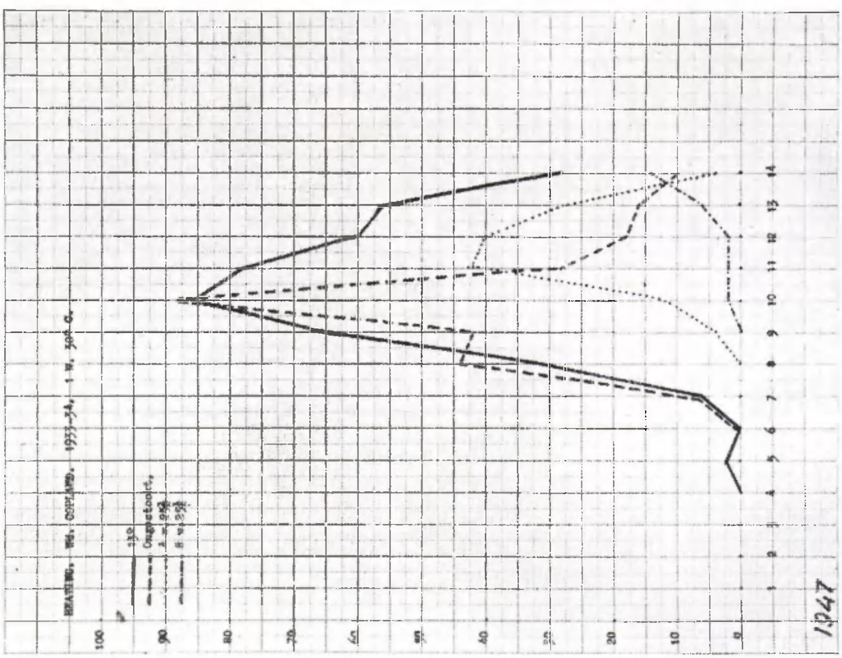

Fig. 19. Percentage of flowers of Darwin tulips William Copland damaged after a heating dose of one week 30° C. (86° F.) from 1 August till 17. Oct. 1934. Influence of Pre-treatment.

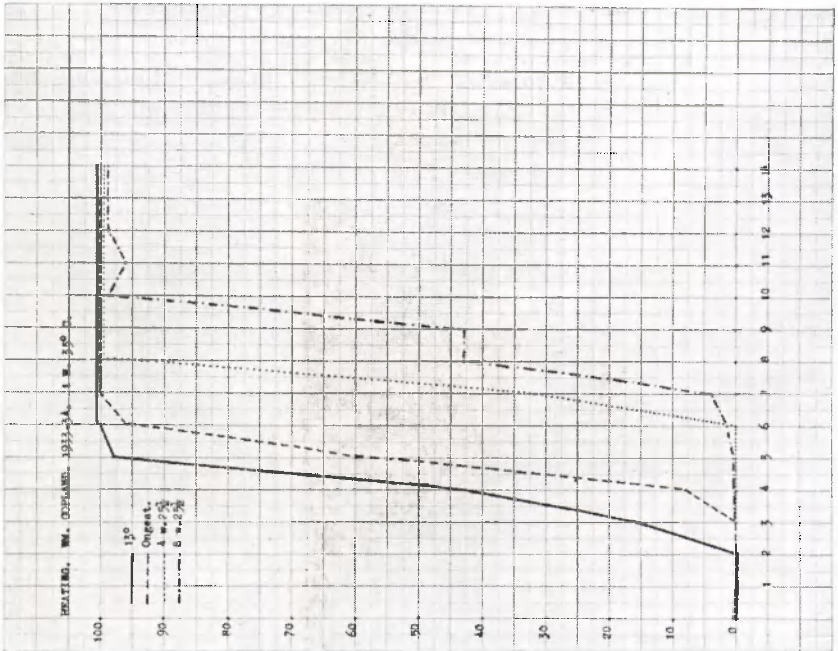

Fig. 20. Percentage of flowers damaged after a heating dose of 1 week 35° C. (95° F.).

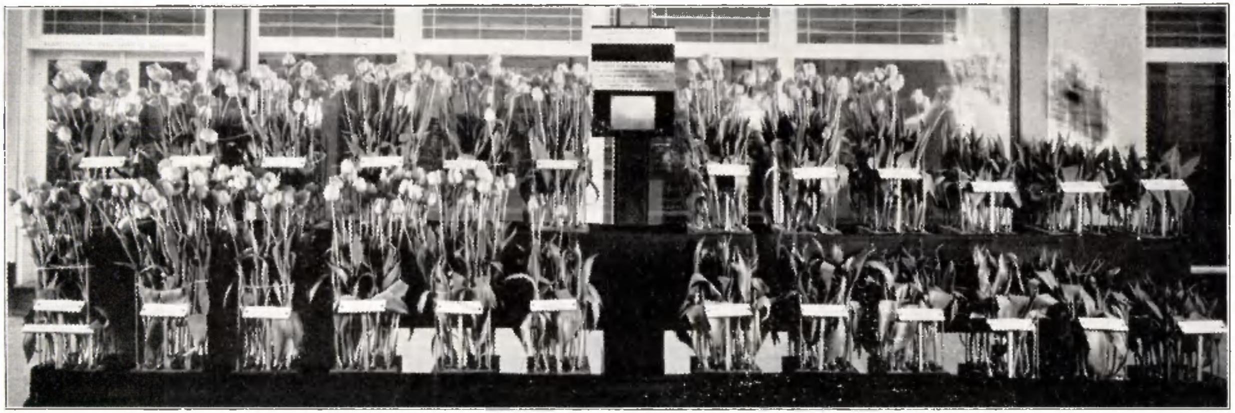

Fig. 21. Two series of tulips Wm. Copland: Upper row: Pretreated at $25\frac{1}{2}$° C. (78° F.) for 8 weeks. Lower row: normal treatment, storage at 17—20° C. (62,6—68° F.). Influence on the flowering of one week 30° C. (86° F.) beginning on 1 Aug. — 8 Aug. — 15 Aug. — till 17 Oct. After normal treatment the damage first appeared on 29 Aug. After special treatment the damage first appeared on 26 Sept. The Percentage of damaged flowers was:

upper row: untreated:	0	0	0	0	0	0	0	0	20	100	100	100
lower row: normal:	0	0	0	0	16	88	100	100	100	100	100	100

made them often worthless, because "heating in transit" had more or less seriously damaged or even entirely destroyed the flowerbuds.

The greatest care we have bestowed on our bulbs becomes so often worthless.

I show you a few photographs on which you can observe various stages of damage, we found in bulbs send to us from all parts of the world as well as in bulbs experimentally treated for the investigation of this important problem.

You certainly will understand that bulbs which have been planted to give delight by their beautiful flowers in spring, and do give such a result, do not satisfy the ultimate consumer of our products.

We have found that the sensitiveness for this damage strongly varies during the season.

This increases first and later on it is again decreasing, as is shown in the next projection (fig. 19, 20).

It does not need a very high temperature dosis to get this damage; only one week 30°C. But most important is, that the pre-treatment of the bulbs highly influences the damage and farther that again the bulbs which have had the so-called optimal treatment for early forcing, most easely are damaged by heating in transit.

We have been able by a special treatment for 4 to 8 weeks at $25^1/_2$ °C. to delay this most sensitive period for about four to five weeks, that is to the time when the climate of the region where the bulbs have to be forced has become much more favourable and less dangerous for their flowering-capacities.

In connection with this problem we have to study also the climatic conditions in the different countries where our bulbs are used.

In all cases however we have to give due attention again to the influence of all this treatments on their fittness for early or later forcing and from this, I hope, it will be once more clear that for a sufficient insight in the multilateral requirements of our products in the first place we need a very close contact with our living plants in their natural surroundings and a less close contact with the culture in all her demands, must of necessity lead to insufficient contact with her problems.

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[1] *Beijer* and *van Slogteren*, Weekblad voor Bloembollencultuur **1930**, **1931**, **1932**, **1933**. — [2] *Dolk* and *van Slogteren*, Gartenbauwiss. **4**, H. 2 (1930). — [3] *Van Slogteren*, Daffodil-Yearbook **1933** and **1935**. — [4] *Blaauw*, *Hartsema* and *Huisman*, Proc. Kon. Akad. v. Wetensch. **1932**. — [5] *Beijer*, Weekblad voor Bloembollencultuur **1936**. — [6] *Algera*, Proc. Kon. Akad. v. Wetensch. **1936**.