

Botany. — *On the atmospheric humidity during the flower-formation of the Hyacinth.* By Prof. A. H. BLAAUW. (Communication N^o. 23. Laboratory for Plant-physiological Research, Wageningen.)

(Communicated at the meeting of January 29, 1927).

§ 1. *Introduction.*

Between the lifting and planting of the Hyacinths, i.e. from the beginning of July to the beginning of October, lies the important period, in which the bulbs pass on to flower-formation and in which a good flowering for the next year, — or if desired the early flowering in December — entirely depends on the adequate treatment. With regard to this we have first of all to deal with the temperature as most important factor. Hence the influence of the temperature was first investigated into, and part of these researches were already published, whilst further papers on this subject will follow after being worked out.

The only other important factor might be the hygrometric condition of the air. The bulbs have just received the assimilation-products from the leaves. It is often said — and frequently not unjustly — that the concentration of the assimilation-products enables a plant, during vigorous cell-division, to pass on to flower-formation. This makes us ask ourselves whether, when the concentration is forwarded by a dry atmosphere, so that the bulbs evaporate a great deal of water, the assimilation-products do not accumulate more inward and in this way the atmospheric humidity may influence the flower-formation.

In practice the growers often talk of "dry-storing" and the question rises whether drought is really favorable for the growing plant, in what degree and whether from July to October the drought should be equal or varied. Questions, therefore, essential both to the theory of flower-formation and leaf-development and to the application.

Based on experiments fully described and on the fact that the temperature is the most important factor after all, we stick to the optimal temperature-treatment for field-cultures; after the lifting till ca Sept. 1 (ca 8 weeks) 25° to 26°, next till the planting (ca 4½ weeks) 17° at most.

After having repeated experiments on the hygrometric condition of the air for 3 summers, I shall communicate their results here.

For reading the hygrometric condition of the air, expressed in percents of the saturation, we chose of various makes or systems as the most practical for our use the hair-hygrometers of RICHARD in the shape of an alarmclock (Hygromètre à cadran; section of dial 10 cms.). There are those among them which are unsuitable for some reason; therefore a

choice should be made and those taken into use which are sensitive enough and which in spite of a change of temperature or humidity, when reduced to the same circumstances almost point to the same hygrometric condition. The correct height of the Hygrometer is regulated by repeated comparison with the Assmanns-Aspiration-psychrometer, i.e. "gauged", which regulation is easily performed by adjusting the hand.

Next 4 experiments were compared each year, viz. the first hot period (26°) moist, the second cooler period (17°) dry, indicated *VD*, or first dry then moist (*DV*), or both periods dry (*DD*) or both periods moist (*VV*).

The bulbs were put in glass or china dishes in two zinc boxes. Those boxes were put on their sides, the open "upper side" turned towards the front, slightly sloping backwards, a glass-plate against them. The dry box contained (besides the bulbs and a hygrometer) a dish of unslacked lime for drying, which was renewed as soon as the humidity approached the fixed upper limit. The moist box was kept at the desired moisture by a little water at the bottom or by an evaporation-tube (of a radiator of the central heating). The chinks between the glass and zinc box were covered with moist cloths if necessary.

For the drought (*D*) the hygrometric condition was kept at 30—40 % in all three summers, for the moisture (*V*) in 1923 first at 80—90 %, in 1924 and 1925 even at 90—100 %, as a rule 95—100 %. On purpose strong contrasts were chosen. But as moderately moist and moderately dry might be more favorable than one of these four extremes, after the result of 1923 a 5th group was added in 1924 and 1925, in which fairly moist amounted to 70—80 % and fairly dry to 50—60 %. This 5th group has been indicated as "control group" in the following tables.

In the very moist treatment there naturally occurred mould, only however on the totally exhausted outer scales and the bottom disc-layer. On account of this these bulbs were cleaned a few times with a cloth. Rotting or injury to living parts did not occur in spite of the very high moisture-content.

§ 2. *Experiments in the year 1923—1924.*

In the summer of 1923 2 year old bulbs were chosen of a circumference of 80—90 cms. By that time the different experimental groups were selected only according to the circumference and not yet — as always happened in later years — divided into groups of equal weight.

Consequently in October after the treatment there was a certain variation between the weights of the 30 bulbs (per experiment), which variation is arbitrary and cannot just be attributed to the previous treatment (See Tab. 1).

Of the 30 bulbs treated per experiment some 9 were lifted afterwards in order to trace whether the humidity had any effect on the root-system.

Various data on the root-system, also in connection with different circumstances, have been examined and will be published in a separate treatise by Mrs. M. C. TROOST—VERSLUYS.

Results 1923—1924.

Though in February 1924 the group *VD* came up somewhat later than the three other groups, yet on March 26 all four groups were perfectly equal. Likewise on April 22nd all groups were uniform and in full flower, so that not the slightest distinction could be made as a result of the treatments.

An influence on the number of foliage-leaves may hardly be expected, since on lifting the foliage-leaf-formation ceases and at 26° the growing-point passes on to flower-formation. Yet with so severe a drought (e.g. in *DD* and *DV*) contrasted with a high moisture-content (in *VD* and *VV*) the leaf-formation might cease at different points of time, and at any rate an influence on the shooting or non-shooting of the last-formed leaflets was not unthinkable. In Tab. 1, first column, we see that after the treatments of 1923 the number of shooted foliage-leaves computed for 10 bulbs was identical (38) averagely in three groups, in *VV* slightly smaller (36), but this difference of upwards of 5 % may be quite accidental. In *VV*, therefore, the influence on this is at most very slight; in the three other cases the shooting is at all events the same. We shall revert to this in the further experiments.

TABLE 1. Treated summer 1923, beginning of July 80—90 mms.

Treatment 1	Weight per 20 bulbs. Be- ginning of Oct. 1923 after treatment 2	Number of shooted foliage- leaves per 10 bulbs 3	Number of flowers per 10 plants (<i>n</i> = 30) 4	Average length of the foliage above ground in mms. 5	Weight per 20 bulbs July 6, 1924 6	Average circumference per bulb July 6, 1924. 7
VV	199 Grams	36	62.4 (± 2.7)	334.6 (± 4.3)	640	125.8 mms. (± 2.0)
DD	201 ..	38	62.0 (± 2.4)	313.9 (± 7.4)	586	118.1 .. (± 2.2)
DV	209 ..	38	63.7 (± 2.5)	311.9 (± 6.5)	596	121.9 .. (± 2.1)
VD	194 ..	38	66.0 (± 2.3)	342.4 (± 3.5)	702	131.7 .. (± 1.6)

In this first year there initially seemed to be not the slightest difference between the four groups. The four lots flowered particularly uniformly. The average number of flowers per cluster is still slight in these small bulbs. Column 4 gives the number per 10 plants as an average from 30 specimens after the different moisture-treatment in the previous summer. That number is also equal in the four groups. True, after *VD* the number seems slightly higher, but the difference does not exceed the amount possible according to the mean errors.

At the beginning of May after the roping of the flowers the foliage was also perfectly equal. Not before the end of May and the beginning of June the length of the foliage-leaves in the various groups became unequal. At the end of May the length of the foliage was measured above ground. Column 5 shows that there certainly is a difference in length here, even though the mean error is taken into account. The two groups *V V* and especially *V D* as averages of 20 observations are clearly 2 and 3 cms. longer than those which were first treated dry.

While the leaves were still growing out in June, no further measures could be taken, because by that time the leaf-apexes begin to dry up, though the rest of the leaf is still assimilating. It is however more important to trace the effect of the assimilation-period in the increase of weight (or increase of circumference).

In Tab. 1 columns 6 and 7 show us the following :

The weight per 20 bulbs rather varies at the beginning of Oct. 1923 ; this, however, does not prove anything with regard to more or less evaporation, since in July the groups had not yet been divided according to equal weights as later on (see 1924 and 1925).

The difference in increase of the bulbs after different moisture-treatment (previously between lifting and planting) was so striking in 1923—1924, that we understood that these experiments ought to be continued and repeated. The very bulbs which chanced to have the lowest weight at the beginning of Oct., i.e. after the treatment and before the planting, have by far the greater weight on July 6, 1924. Those are the two groups which were kept extremely moist for two months after the lifting, whilst the greatest increase in weight was shown by the one that was kept very dry at 17° after that.

So it appears from four groups, *that at all events during the flower-forming period a very moist atmosphere has a more favorable effect on the increase in thickness of the bulbs than a dry atmosphere in July and August*, whilst no detriment e.g. concerning diseases was noticed. This result we ourselves had not surmised at all ; it already proves that the idea "dry-storing" often used in practice, is put in a peculiar light. We shall however first have to consider the results of following years. In Tab. I the average circumference on July 6 has also been given. From this the same results can be read as from the column of the weights of the four groups. Apparently the circumferences do not diverge so much as the weights or the increases of weight. But these two criteria form an essential point for comparison of magnitudes as we repeatedly want them. *With the weights we have to deal with a comparison of the heaviness of certain bodies, i.e. we compare with each other three-dimensional magnitudes. With the circumferences we only compare a certain linear measure of those same bodies.* Therefore on our comparing the circumferences the difference of the real contents will be much less conspicuous than on our comparing groups of bulbs by their weights. Hence after having exclusively worked

with circumferences in the first years, we now in particular compare the weights in our experiments, wherever this is possible.

Meanwhile we have already got a great number of data on weight and circumference of bulbs, so that afterwards we shall probably revert to the connection between these two magnitudes,

§ 3. *Experiments of the years 1924—1925 and 1925—1926.*

In this § 3 the results of 1924—1925 and 1925—1926 will be discussed together. The experiments were started on July 9, 1924 with bulbs having a circumference of 110—120 mms., weighing 518 grams per 20; in 1925 the experiments were started on July 3 with bulbs of 115—120 mms., i.e. selected within slightly narrower limits, weighing 531 grams per 20, so somewhat heavier than in 1924, which corresponds with the limits of circumference which were chosen 115—120 mms. instead of 110—120 mms.

As was already stated in the conclusion of § 1, a control-group has been added of fairly moist ($25\frac{1}{2}^{\circ}$ C.) + fairly dry (17° C.).

Mid-September 1924 in *V V* the roots had already shooted so far, that this group had to be planted in the field with great care.

Thus *V V* of 1924 was planted with shooting roots in the field upwards of 14 days earlier than all other groups. In 1925 this did not occur in *V V*, though the root-whorl was already much developed on Oct. 1.

In the spring of both years all five groups first mutually behaved similarly, just as the four groups in the first year did.

Here the question first rises whether there is any influence on the number of flowers. In April 1925 the average is 13 to 14 per cluster in the control-group, *V V* and *V D*, compared to 15 to 16 in *DD* and *D V*; taking the mean error into consideration we might decide here on a slight difference in favour of *DD* and *D V*.

TABLE 2. Number of flowers per cluster in April after the different moisture-treatments in the previous summer,

	Circumference 110—120 mms. April 1925	Circumference 115—120 mms. April 1926
Control-group	12.9 (\pm 0.5)	12.8 (\pm 0.4)
VV	13.3 (\pm 0.8)	12.0 (\pm 0.4)
DD	15.2 (\pm 0.6)	12.5 (\pm 0.5)
DV	15.8 (\pm 0.6)	12.1 (\pm 0.5)
VD	14.2 (\pm 0.7)	12.8 (\pm 0.4)

On our considering the experiment of 1925—1926, we see that the number of flowers of an average of 12 to 13 per cluster differs very little in all 5 groups. The mean errors should be taken into account — and it should likewise be borne in mind, that in the more accurately selected material the mean error (computed for groups of 20) is also visibly slighter.

After having repeated these experiments for 3 years, we must conclude, *that the atmospheric moisture (between 30 % and 100 %) has no noticeable effect on the number of flowers of the cluster in the flower-forming period.*

Let us now consider as with the experiments of 1923—1924 how many foliage-leaves shoot and assimilate in the spring. For 1925 and 1926 this is found in Table 3. In the 5 groups of 1924—1925 this number varies from 48 to 51, in 1925—1926 from 51—55 per 10 plants. This difference per 10 plants is certainly slight. In this respect too we must conclude

TABLE 3. Number of foliage-leaves shooted per 10 bulbs.

	1925	1926
Control-group	51	55
VV	48	51
DD	49	52
DV	50	52
VD	49	53

after comparison of the results of 3 years from 4 and 5 groups, *that the hygrometric condition of the air between 30 % and 100 % has no noticeable effect on the shooting of the number of young leaves already formed, which are to assimilate next spring.*

Moreover we see that *during the flowering and a short time after in April the foliage is uniform in the various groups.*

It was already mentioned in the first series of experiments, how in June 1924 at last a striking dissimilarity was observed, because finally the foliage of group *VD* grew a good deal longer, which was corroborated in the results, because the increase of weight in this group was by far the greatest.

Table 4 gives the average length of the foliage in the beginning of June 1925 and 1926. Already in this case with the leaf-lengths, but still more so from the subsequent tables 5 and 6 on the increase in weight it appears, that 1925 was a more favorable year for assimilation than 1926.

TABLE 4. Average length of the foliage in mms. above ground, beginning of June, after different moisture-treatments in the previous summer.

	Circumference 110—120 mms. June 1925	Circumference 115—120 mms. June 1926
Control-group	293.1 (\pm 4.5)	283.0 (\pm 5.1)
VV	315.8 (\pm 7.9)	260.5 (\pm 7.0)
DD	307.0 (\pm 7.4)	286.1 (\pm 5.8)
DV	288.0 (\pm 9.3)	275.5 (\pm 9.5)
VD	320.7 (\pm 5.2)	291.6 (\pm 5.8)

With regard to the Hyacinth it may make a great difference whether the winter lasts long and is followed by a warm, dry early summer, or that we have a rather early mild spring passing into a moderately warm and rather moist early summer. The assimilation-period, as it is already very limited for the Hyacinth may be very short or rather long in consequence of this.

Hence the result of experiments can be so divergent one year and an other, though we compare the effect of treatments applied to the bulbs in summer under completely controlled conditions.

In Tab. 4 we give the average length of the foliage in mms. above ground ca June 1. Little may be concluded from this. Considering the mean errors, the differences are rather slight in most cases. Yet in both

TABLE 5. Increase of weight in grams per 20 bulbs.
Treated summer 1924. Circumference 1924: 110—120 mms.

	Weight 20 bulbs July 9, 1924	Weight Sept. 30, 1924	Weight 20 bulbs July 8, 1925	Increase in a year
Contr.	518	448	933	415
V V	518	planted earlier see text	908	390
D D	518	421	890	372
D V	518	441	869	351
V D	518	433	941	423

TABLE 6. Increase of weight in grams per 20 bulbs.
Treated summer 1925. Circumference 1925: 115—120 mms.

	Weight 20 bulbs July 3, 1925	Weight Sept. 30, 1925	Weight Juni 28, 1926	Increase in a year
Contr.	531	413	779	248
V V	531	449	718	187
D D	531	397	746	215
D V	531	422	788	257
V D	531	420	821	290

years the foliage is longest in *VD*. In 1926 *V V* yields a fairly low figure, while this group succeeded *VD* in foliage-length in 1924 and 1925. Taking all together we should not attach too much value to this measure of the leaf-lengths; we can only say that the phenomenon of 1924 "that after the treatment *VD* the leaves finally attain a somewhat greater length" is confirmed in 1925 and 1926, though it is not so striking as in 1924.

Let us finally consider the increase of weight in 1925 and 1926. First of all these tables 5 and 6 prove that with slight differences in leaf-lengths as in Tab. 4 we should be careful and that these are not quite parallel with the increase in thickness of the bulbs. Only in case of somewhat greater differences we may rely to some extent on the foliage-lengths. So we find that in 1925 and 1926 the groups with the longest and with the shortest foliage are likewise the best and the worst group as regards the weight.

In Table 6 attention should be paid first of all to the loss of weight of the bulbs directly after the treatment. As regards the evaporation, of course this depends greatly on the moisture or drought of the storage-atmosphere. Starting from 531 grams the group *V V* has lost 82 grams or 15 %, the group *D D* 25 % (in 1925 but 19 %), while the other groups lost an amount between those two extremes. We see that even with 90—100 % moisture the loss of weight though much slighter, is yet considerable (15 %). This loss of weight will for the greater part be due to evaporation, but will partly be owing to oxydation. That part of the loss of weight which is due to respiration, may be expected to remain constant in this different atmospheric moisture but uniform temperature-treatment.

Both in 1925 and 1926 this increase of weight at the end of the assimilation-period is greatest after the treatment *VD*, though in 1924 the differences were greater (see Tab. 1). Of the remaining groups little can be said with certainty about the three years. In 1925 the control-group fairly

moist-fairly dry produces a favorable effect, in 1926 a rather favorable, it does not belong to the 2 worst groups. In the three years the worst figure is successively yielded by *DD*, *DV* and *VV*; the least increase but one by the groups *DV*, *DD* and *DD*. While in 1926 *VV* increases strikingly little, this group was fairly favorable in 1924 and 1925. So we see that the groups *DD* and *DV* yield one of the two lowest figures 5 of the 6 times in those three years, the group *VV* but once, while *VD* gives the greatest increase all the 3 times.

§ 4. Conclusion.

We have exposed Hyacinth-bulbs in one and the same temperature-treatment to very moist and very dry conditions and repeated this three years running.

The hygrometric condition (30 %—100 %) of the surrounding air in the period of storing has *no influence on the number of leaves that can shoot the next year*.

The hygrometric condition of the air during that flower-forming period has *no influence on the number and the good development of the flowers*.

Finally the applied moisture is noticeable next summer in the final length of the foliage, as very moist 25° C. followed by very dry 17° C. grows out a little more than all other groups, which was corroborated all the three years.

Probably it may be considered as an additional result that all the three years after this treatment the greatest increase of weight was found, exceeding the results of the other treatments sometimes more, sometimes less. Besides the application of very dry in the first months is by no means favorable, so that dry-dry and dry-moist are far behind moist-dry in increase of weight. Moist-moist is now fairly good, now unfavorable and should be avoided, because of the danger that the roots will shoot untimely in 17° in September.

A moisture of 90—100 % followed by 20—40 % is difficult to apply on a large scale. In great quantities the growing mouldy and the decay of old bulb-rests might yield a too great danger for the living parts of the bulb (which however could not be observed by us in small quantities). Moreover a drought of 30—40 % moisture is difficult to maintain in the large stores.

After the lifting of the bulbs we keep our rooms dry for a couple of days, until sand and root-rests get loose from the bulbs, next we raise the temperature to 26° C. and the moisture to 70—80 % for 8 weeks for the field-cultures. After 8 weeks we transfer to 17° C. with a moisture of 50—55 %.

Though on applying fairly moist and fairly dry the advantage of very moist—very dry is partly given up (see control-group in tables 5 and 6), the difficulties of applying very moist and very dry on a large scale as in our experiments, are avoided in that way.

Thus the hygrometric condition cannot act a great part in the application to considerable quantities. A moisture of 90—100 % followed by 30 % would certainly produce a greater increase of weight, but because of the difficulties of application we shall have to be satisfied with fairly moist (70—80 %) followed by fairly dry (50—55 %).

January 1927.
