Physiology, morphology and growth responses of gladiolus corms as influenced by storage temperatures

David C. Fairburn
Iowa State College

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PHYSIOLOGY, MORPHOLOGY AND GROWTH RESPONSES
OF GLADIOLUS CORMS AS INFLUENCED BY
STORAGE TEMPERATURES

BY

David C. Fairburn

A Thesis Submitted to the Graduate Faculty
for the Degree

DOCTOR OF PHILOSOPHY

Major Subject Horticulture

Approved:

Signature was redacted for privacy.

In charge of Major work

Signature was redacted for privacy.

Head of Major Department

Signature was redacted for privacy.

Dean of Graduate College

Iowa State College

1932
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INTRODUCTION

In recent years the commercial production of gladiolus corms has experienced a phenomenal expansion. This attractive flower has advanced in popularity until it is now recognized as one of the most desirable garden and commercial greenhouse subjects. A census compiled by the United States Department of Agriculture (20) shows that the gladiolus is grown more commonly over a greater area than any other bulbous plant, the estimated sales for 1930 being 153,500,000 corms.

The gladiolus is a tender perennial and will not survive in regions where the winters are severe. Therefore, in the fall of the year the corms must be removed from the garden and stored until planting time in the spring. The conditions to which the corms are exposed during this dormant period determine to a large extent the growth response the following season. Since winter storage conditions have such a decided influence, this phase of gladiolus culture is of great importance. The present knowledge on this subject is based mostly on the casual observations of practical growers, and the need for further study is obvious. This investigation is concerned with the physiology, morphology and growth responses of gladiolus corms and is designed to contribute more exact information regarding the problem of storage temperatures.
1. Respiration

In a study of plant respiration there are many factors to be considered, as for example temperature, moisture, aeration, enzymatic action and maturity. Since temperature is apt to be the most variable and possibly the most important single factor, it was selected as a basis for this report.

A survey of the current literature on respiration has to date disclosed nothing concerning the gladiolus. Consequently, it is necessary to cite material that is indirectly related to the question in order to afford a general perspective of the field. More extensive references on the subject of respiration may be found in Kostychev (24) and Miller (28).

Other factors being equal, the rate of plant respiration is, within certain limits, directly proportional to the prevailing temperature. This is well emphasized by Bailey and Gurjar (5) who found that increasing the temperature accelerates the rate of respiration of stored wheat until 55° C. is reached. Hopkins (21) working with potato tubers reports that the respiration curve does not consistently decline as the temperature decreases, but declines to a low point at 3° C., increases at 0° C. and then
It can be seen during the latter part of the season, the changes probably accompanied by a disappearance of starch, that the starch is used up gradually by a gradient decrease of starch during the first of the storage season with a gradual decrease of starch, and then reached an entirely different quantity. Such a decrease rather consistent during the first storage season, and then reached practically to the original storage sugars increased gradually until about the middle of the gradient loss of starch during the entire storage season. Hesseltine (19) working with Mariesneux pears found a gradient decrease of nitrogen-nitrogen variations.

2. Carbonate-nitrogen variations.

between different varieties are predicted.

in respiration intensity over short periods of time and variations increase proportionately as the temperature rises. The changes expected that the respiration rate of radishes comes with the increase of the temperature until the death of the plant from high temperature. Treatment until a maximum is reached, then the rate remains constant after increase due to increases regularly with a gradient increase in temperature. Cox (94) states that the amount of carbon dioxide the respiration of green bananas varies with the temperature and age in dimensions. A close correlation between temperature and
in reducing sugars were less marked than those of cane sugar. The changes in starch and cane sugar appeared in a general way to be correlated with the seasonal changes in the temperature. In sweet potatoes stored at 4°C, there was a rapid disappearance of starch and an accompanying increase in cane sugar. The quantity of invert sugar in the root at any one time was comparatively small.

Appleman (2) reports that after-ripening does not involve the hydrolysis of proteins in potato tubers. The metabolic changes, including the changes in the nitrogenous materials, begin rather suddenly and are concurrent with sprouting. Newton (30), working with the nitrogenous compounds in dormant and non-dormant potato tubers, did not consider the stimulation of growth by nitrates to be due to an internal deficiency of soluble nitrogen compounds.

3. Morphology

Considerable information is available regarding the development of vegetative and floral tissue of gladiolus and other bulbous plants. In a histological study of flower formation Jones (22), (23) found that primordia of flowers of gladiolus are formed a few weeks after the corms are planted. Using chemically treated corms which were planted in the fall and forced in the greenhouse, Pfeiffer (31) detected flower primordia in the variety Halley seven weeks after growth started, while in
Alice Tiplady there was no evidence of flower formation until about ten weeks after growth started. Watkins (36) studied the progressive development of gladiolus buds from the beginning of storage to complete differentiation and reports evidence of the flower spike soon after growth has started during the current growing season. Souvenir showed a well defined flower spike thirty days after planting. The time of flower differentiation varied with different varieties. Zweede (38) working with Convallaria majalis found the growing point at rest from October until March. After this period of rest it was soon evident whether a flower cluster would be formed. It is interesting to note that Blaauw (9) reports all stages of development present at all periods of the year in Hippeastrum hybridum. This is a significant difference, for with most other plants as tulip, hyacinth, Convallaria, lilac and Rhododendron young flower-stages are found only in one limited period of the year.

Work on hyacinth by Blaauw (6) has indicated that storage temperatures may stimulate or inhibit flower development. A temperature of 25.5°C. for eight weeks followed by 17°C. for four weeks is recommended. Blaauw and his associates (7), (8), (29), working on the Darwin-Tulip, Pride of Haarlem, have found that the processes of flower formation in the tulip occur at lower temperatures than are necessary for the hyacinth.
EXPERIMENTAL

1. RESPIRATION
Materials and Methods

Materials

In the spring of 1930, corms of the gladiolus varieties Giant Nymph and Souvenir were obtained for this investigation from a commercial gladiolus grower in Iowa. These corms were then planted on fertile loam soil, the new corms harvested late in the fall, and used in the respiration experiments of 1930-31. The next year (1931-32) new corms of these same varieties were grown and used in further respiration studies.

The respiration apparatus is shown in Plate I. The air is drawn through a purification train which includes two small bottles containing 50 percent potassium hydroxide to remove traces of carbon dioxide and two large bottles containing 45 percent sulphuric acid to obtain an approximate relative humidity of 50 percent in the respiration chamber. The respiration chamber consists of a heavy glass battery jar fitted with an air tight plate glass lid in which there are three one-inch holes to provide for the intake and exit of air. Carbon dioxide-free air is introduced either at the top or at the center of the chamber by manipulating the pinch clamps. This intake at the center of the jar is recommended in order to sweep out any accumulated carbon dioxide before making a determination. A glass tube leading from the bottom of the jar provides the exit. The plate glass lid is cemented to the top of the jar.
with shellac.

By means of glass Y tubes and pinch clamps the air is drawn either directly to the flow-meter or through the Truog absorption tower (34) and provides for constant aspiration while the absorption tower is being attached to the system. A trap bottle containing barium hydroxide is used to check the efficiency of the absorption tower. The flow-meter regulates the amount of air passing through the apparatus, and a constant flow of air is maintained by suction from a water pump. Fluctuations in the suction caused by variations in the water pressure are prevented by inserting a pressure regulator adjusted to a pressure of 6.61 cm. mercury between the suction pump and the flow-meters.

Cold storage rooms provided constant temperatures of 0°, 5° and 10°C. Temperatures of 21° and 32°C. were obtained with a water bath regulated with running water and an electric oven with thermostatic control.

Methods

In 1930-31 the corms of Souvenir were not satisfactory for the experiment owing to poor development during the growing season; the observations were confined, therefore, to the variety Giant Nymph. The freshly harvested corms, size No. 2, were dried at 25°C. for three days, cleaned and placed in storage at 10°C. until the respiration apparatus was available.
On December 8 duplicate 2203 gm. samples of these Giant Nymph corms were placed in the respiration chambers at temperatures of 0°, 5° and 10°C. Intermittent carbon dioxide determinations were made throughout the storage period until May 8.

The air was drawn through the apparatus at the rate of 10 liters per hour. This provided for a complete change of air in the respiration chamber at least once every hour. The carbon dioxide was passed through the absorption tower containing a known quantity of 0.2 N. barium hydroxide, and the excess alkali titrated against 0.2 N. hydrochloric acid, using phenolphthalein as an indicator.

Number one corms of Giant Nymph and Souvenir were used in the respiration studies of 1931-32. On October 18 a sample of 2931 gm. was selected from each variety and placed in the respiration chambers at temperatures of 10°, 21° and 32°C. Carbon dioxide determinations were made as previously described.
Explanation: Plate I

Observations left to right -

1. Two small bottles of 50 percent KOH
2. Two large bottles of 43 percent H$_2$SO$_4$
3. Respiration chamber
4. Truog absorption tower
5. Trap bottle of Ba(OH)$_2$
6. Flow meter
Respiration of Giant Nymph at $0^\circ$, $5^\circ$ and $10^\circ$C.

1930-31

The data for this investigation are given in table I and graphically presented by figure 1. On December 23 the respiration chambers had to be dismantled to control the growth of mold on the corms, accounting for the break in the data. The corms were dipped in a solution of corrosive sublimate, dried and the experiment continued from January 2. One-quarter inch wire netting was placed between the layers of corms to provide better air circulation. No further trouble with mold developed.

It is evident that gladiolus corms do not respire at a rapid rate when stored at low temperatures, especially at $0^\circ$C. As a matter of comparison it may be said that the rate of respiration of corms approximates that of apples as reported by Harding (15). The period of most rapid respiratory activity occurred at the beginning of storage. The rate decreased sharply during the first few weeks of storage and then diminished gradually with decided fluctuations at certain periods. This tendency was more pronounced at $5^\circ$ and $10^\circ$C. than at $0^\circ$C., although in general the rate of respiration increased with the temperature; after 90 days in storage the respective rates were approximately the same, and at the end of the storage period no large differences were found. It appears that factors other
than temperature may have an important influence on the physiological behavior of corms in storage.

**TABLE I**

The Rate of Respiration of Giant Nymph Corms Stored at 0°C, 5°C and 10°C. Results expressed in mg. of CO₂ per sample per hour.

*Jars dismantled on account of mold accumulation*
RESPIRATION RATE OF GIANT NYMPHS STORED AT 0°, 5°, AND 10° C.

Figure 1
Respiration of Giant Nymph and Souvenir at 10⁰, 21⁰ and 32⁰C. 1931-32

Before the experiment was started the corms were treated with corrosive sublimate to avoid the difficulties with mold experienced the previous year. However, another troublesome factor developed which necessitated slight changes in the apparatus. At 21⁰ and 32⁰C. considerable quantities of water collected in the respiration chambers and connecting tubes, often resulting in the flooding of the flow-meters. The excess moisture was eliminated by substituting calcium chloride tubes for the sulfuric acid bottles in order to pass dry air into the respiration chambers.

The data are given in table II and graphically presented in figures 2 and 3. A decided increase in the respiration rate accompanied a rise in temperature. A gradual decrease in the rate was evident with the greatest decline occurring early in the storage period, particularly at 10⁰ and 21⁰C. At 32⁰C. the rate diminished rapidly at first, and then continued at a decidedly higher value than at 10⁰ and 21⁰C. Towards the end of the storage period there was an increase in the respiration at 32⁰C., which is attributed to sprouting of the corms. Fluctuations in the rate of respiration at various periods were again common. Souvenir corms respired at a more rapid rate than did Giant Nymph corms and it is assumed that
this fact is associated with the shorter life cycle of the Souvenir variety.

**TABLE II**

The Rate of Respiration of Giant Nymph and Souvenir Corms stored at 10°C, 21°C and 32°C. Results expressed as mg. of CO₂ per sample per hour

<table>
<thead>
<tr>
<th>Dates of</th>
<th>10°C</th>
<th>21°C</th>
<th>32°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>determinations: Giant: Nymph</td>
<td>Souvenir: Nymph</td>
<td>Souvenir</td>
<td></td>
</tr>
<tr>
<td>Oct. 16</td>
<td>50.6</td>
<td>52.0</td>
<td>57.2</td>
</tr>
<tr>
<td>Oct. 19</td>
<td>:</td>
<td>:</td>
<td>50.2</td>
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<tr>
<td>Oct. 20</td>
<td>:</td>
<td>:</td>
<td>46.5</td>
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<tr>
<td>Oct. 21</td>
<td>48.6</td>
<td>61.0</td>
<td>:</td>
</tr>
<tr>
<td>Oct. 22</td>
<td>:</td>
<td>41.0</td>
<td>:</td>
</tr>
<tr>
<td>Oct. 23</td>
<td>44.1</td>
<td>51.8</td>
<td>:</td>
</tr>
<tr>
<td>Oct. 24</td>
<td>:</td>
<td>38.3</td>
<td>:</td>
</tr>
<tr>
<td>Oct. 25</td>
<td>41.3</td>
<td>48.3</td>
<td>:</td>
</tr>
<tr>
<td>Oct. 26</td>
<td>:</td>
<td>40.9</td>
<td>47.9</td>
</tr>
<tr>
<td>Nov. 1</td>
<td>36.1</td>
<td>34.5</td>
<td>28.4</td>
</tr>
<tr>
<td>Nov. 7</td>
<td>:</td>
<td>:</td>
<td>:</td>
</tr>
<tr>
<td>Nov. 11</td>
<td>26.8</td>
<td>30.5</td>
<td>24.0</td>
</tr>
<tr>
<td>Nov. 15</td>
<td>24.4</td>
<td>28.4</td>
<td>21.4</td>
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<tr>
<td>Nov. 19</td>
<td>26.0</td>
<td>27.0</td>
<td>19.1</td>
</tr>
<tr>
<td>Dec. 2</td>
<td>23.8</td>
<td>:</td>
<td>15.6</td>
</tr>
<tr>
<td>Dec. 10</td>
<td>:</td>
<td>16.4</td>
<td>26.0</td>
</tr>
<tr>
<td>Dec. 11</td>
<td>19.5</td>
<td>22.6</td>
<td>:</td>
</tr>
<tr>
<td>Dec. 25</td>
<td>17.6</td>
<td>23.0</td>
<td>15.6</td>
</tr>
<tr>
<td>Jan. 11</td>
<td>13.4</td>
<td>21.0</td>
<td>13.3</td>
</tr>
<tr>
<td>Jan. 29</td>
<td>18.0</td>
<td>25.0</td>
<td>19.5</td>
</tr>
<tr>
<td>Feb. 8</td>
<td>16.5</td>
<td>20.2</td>
<td>17.2</td>
</tr>
</tbody>
</table>
GAJNT NYPH

RESPIRATION RATE OF CORMS
STORED AT 10°, 21°, AND 32°C.

Figure 2
SOUVENIR

RESPIRATION RATE OF CORMS
STORED AT 10°, 21° AND 32° C.

Figure 3
Shrinkage

In the fall of 1931 representative samples of Giant Nymph and Souvenir corms were stored at 25°C. with a relative humidity of 15 to 20 percent. The loss in weight was recorded over a period of 30 weeks. From these data, graphically presented in figure 4, it is evident that a striking uniformity exists in the rate of shrinkage in the two varieties. The total shrinkage was 32 percent of the original weight, with 55 percent of this loss occurring within the first 15 days of storage. This period of rapid shrinkage takes place within three weeks after the corms are harvested, or during the curing process as practiced commercially. Throughout the remainder of the storage period the corms lost 14.4 percent of the original weight.

Investigations on hyacinths by Blaauw (6) have shown that the average loss of weight per bulb over a period of 12 weeks storage was nearly 20 percent of the weight after harvesting. It was further noted that this loss of weight diverges very little at temperatures from 1\(^\circ\)C. to 35\(^\circ\)C. Mulder and Blaauw (29) report a 6 percent loss in weight for tulips.

The shrinkage of gladiolus corms is significant and should be taken into account when calculating the respiratory intensity on a kilogram per hour basis. Since a record of the shrinkage of the corms was not obtained for all the temperatures used, the respiration experiments here reported were calculated on the
Loss in wt. of corms
stored at 25°C.
basis of the total amount respired per sample to afford more accurate comparisons.
2. CARBOHYDRATE-NITROGEN ANALYSES
Get the tissue killed in boiling at once and as quickly as possible of each sample were accompanied within three minutes in order to get percent reduced at the stock. The cutting and weighing millimeter slides. The tissue was weighed and killed in boiling sheaths were removed and cross-sections of the corncobs cut in one sample was a composite of 50 to 70 uniform corncobs. The heel during the middle, and at the end of the storage period. Each corncobs were taken from the respective temperatures at the beegan stored at 10°, 21°, and 32°. One hundred gram samples of these stored for three days, cleaned and placed in storage at 0°. To do in the fall of 1930 freshly harvested topaz corncobs were

Methods

In all the determinations.

Standard analytical equipment and 0.1 percent were used and souvenirs were available for the chemical studies.

The chemical investigations. In 1931-32, 36 corncobs of Grant Nymph fat tablet studies, corncobs of the variety Topaz were selected for since the entire stock of Grant Nymph was required for the res.

Experimental work during the storage season of 1930-31, and corncobs of Souvenir were so small, they were not used for

Materials and Methods

- 25 -
and reduce the probability of error because of enzymatic changes. The tissue was extracted by 15 decantations with hot 80 percent redistilled ethyl alcohol and the extract brought to one liter volume at 25°C.

Carbohydrate analysis

A 50 ml. aliquot of the original liter extract was evaporated to 10 ml. on a water bath to remove the alcohol and 100 ml. of water added to dissolve the sugars. This solution was cleared with neutral lead acetate, brought to 250 ml. volume, filtered and delead with potassium oxalate. When it was necessary to hold the solutions for more than a few hours, a drop of toluene was added and the solutions placed in an ice box.

1. Reducing sugars. Fifty milliliter samples of the cleared extract were used to determine the reducing sugars according to the Munson and Walker method, and the reduced copper determined by the Bertrand method using 0.05 N. potassium permanganate. The quantity of reducing sugar represented is calculated from Munson and Walker's tables.

2. Non-reducing sugars. Seventy-five milliliter aliquots of the cleared extract were hydrolyzed with 5 ml. of concentrated (36 percent) hydrochloric acid by letting the solution stand overnight at a temperature of 35°C. The solution was then neutralized, brought to 100 ml. volume at 25°C., and 25 ml. dupli-
cate samples were used as previously described to determine the quantity of total sugars. The value of the reducing sugars subtracted from the total sugars represents non-reducing sugars.

3. Starch. The oven dried residue was ground to pass a 100 mesh screen and duplicate one-half gram samples used in the determinations. The samples were wet with 50 ml. of water, heated on a boiling water bath for 30 minutes, cooled, and hydrolyzed with takadiastase until no trace of starch could be observed by microscopic examination with an iodine stain. The extract was used in the determination of starch and the residue for acid hydrolyzable substances. The extract was cleared and delead as with the sugar samples. One hundred milliliter of the cleared amylase extract was hydrolyzed for one hour on a boiling water bath with 5 ml. of concentrated (36 percent) hydrochloric acid, neutralized, made to volume, and duplicate 50 ml. samples used for the determination of reducing sugars.

4. Acid hydrolyzable substances. The residue left after enzyme hydrolysis of the starch was washed into a flask with 100 ml. of water and hydrolyzed on a boiling water bath for two and one-half hours without a reflux with 5 ml. of concentrated (36 percent) hydrochloric acid, neutralized, made to volume, and duplicate 50 ml. samples used for the determination of reducing substances.

5. Soluble nitrogen. One hundred milliliters of the original liter extract were evaporated almost to dryness on a water bath
to remove the alcohol and the nitrogen determinations made according to the official Arnold-Gunning Kjeldahl method. Sodium thiosulfate was not used since nitrates were not found in the tissue.

6. Insoluble nitrogen. One gram samples of the dry residue were used for these determinations. The same method was used as with the soluble nitrogen, except that the evaporating process was omitted.
Carbohydrate-Nitrogen Analyses of Topaz Corms
Stored at 0°, 5° and 10°C.

1930-31

The data for this experiment are presented in table III. It will be noted that no figures are given for May at 0°C. The corms at this temperature were destroyed by Penicillium gladioli as illustrated by plate II. Attention is also directed to the inclusion of starch with the acid hydrolyzable substances in the 1930-31 data. In 1931-32 the enzyme hydrolysis was introduced for starch determinations.

The reducing and total sugars are graphically presented in figure 5. A striking accumulation of reducing and non-reducing sugars occurred at 0°C. At 5°C, this accumulation was reduced approximately 50 percent with only a moderate further decline at 10°C. These data are similar to the results of Appleman (1) who found extensive sugar accumulation in potatoes at 0°C. It is evident that the quantity of non-reducing sugars is far in excess of the reducing sugars in gladiolus corms in storage. The quantity of reducing sugars in corms at any one time was comparatively small. Hasselbring and Hawkins (18) report similar results with sweet potatoes. Toward the end of the storage period there was a decrease in both reducing and non-reducing sugars, except at 10°C., where an increase in non-reducing sugars was noted. As the temperature was raised the
sugar content decreased.

The variations in the starch and acid hydrolyzable substances were not consistent. At 10°C, the quantity of polysaccharides gradually decreased as the storage season progressed. It is unfortunate that the data for May at 0°C are lacking; however, it would appear that the starch content of the corms gradually decreased during storage. Since the corms shrink considerably even at low temperatures, the percentage of chemical constituents per unit volume increases. The change is most evident in the case of the polysaccharides and probably accounts for the unbalanced relationship between the increase of total sugars and the decrease of the starch content of the corms.

The variations in the soluble and insoluble nitrogen fractions during storage were not significant. The differences were small and might be due entirely to variations between samples. It would appear that the nitrogen content is relatively stable during storage at low temperatures, as was found to be the case with potato tubers as reported by Appleman (2).
TABLE III
Analyses of Topaz Corms Stored at 0°, 5° and 10° C.
Results Expressed as mg. per 100 gm. Green Sample
Sugars Calculated as d-glucose
1930-31

<table>
<thead>
<tr>
<th>Analysis</th>
<th>0°C</th>
<th>5°C</th>
<th>10°C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Nov</td>
<td>Jan</td>
<td>May</td>
</tr>
<tr>
<td>Reducing sugars</td>
<td>80</td>
<td>1580</td>
<td>*</td>
</tr>
<tr>
<td>Non-reducing sugars</td>
<td>1253</td>
<td>6961</td>
<td></td>
</tr>
<tr>
<td>Total sugars</td>
<td>1333</td>
<td>8661</td>
<td></td>
</tr>
<tr>
<td>Starch and acid:</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>hydrolyzable substances</td>
<td>13940</td>
<td>13940</td>
<td></td>
</tr>
<tr>
<td>Soluble nitrogen</td>
<td>216</td>
<td>226</td>
<td></td>
</tr>
<tr>
<td>Insoluble nitrogen</td>
<td>255</td>
<td>289</td>
<td></td>
</tr>
</tbody>
</table>

*Penicillium gladioli destroyed the corms stored at 0°C.
Figure 5
Explanations: Plate II

Gorms stored at 0°C. infected with Penicillium gladioli.
Carbohydrate-Nitrogen Analyses of Giant Nymph and Souvenir Corms Stored at 10°, 21° and 32°C.

1931-32

The data for this experiment are presented in tables IV and V. Figure 6 shows that a striking decrease in reducing sugars, which was more pronounced at 21° and 32°C., occurred while the corms were in storage. The decline was followed by an increase toward the end of the dormant period in Souvenir, but not in Giant Nymph. This difference in response is attributed to the fact that Souvenir has a shorter dormant period than Giant Nymph. It is also evident that Souvenir has considerably more reducing sugar than Giant Nymph. Such varietal characteristics play an important part in the analysis of plant tissue. The quantity of reducing sugar was inversely proportional to the storage temperature.

In figure 7 there is shown a decided increase in total sugars during storage, more apparent with Giant Nymph than with Souvenir. As the non-reducing sugars increased, the reducing sugars decreased, temperature controlling to a large extent the quantities present. In Souvenir reducing sugars were high and non-reducing sugars low, while with Giant Nymph the situation was reversed. The total sugar content of Giant Nymph varied more than that of Souvenir.

The starch content fluctuated slightly during storage, and definite correlations are obscured by the shrinkage of the corms
which takes place at high temperatures. In general the starch content appears to remain rather constant with a slight decrease occurring as the storage period progresses. The acid hydrolyzable substances showed a definite increase in storage, which might be expected since the percentage of dry matter also increased with the loss of water by evaporation.

The soluble nitrogen content of corms increased in storage, with the greatest increase at the higher temperatures as illustrated in figure 8. The insoluble fraction remained more constant with a slight increase at the middle of the dormant period, followed by a moderate decline toward the end of storage. The insoluble nitrogen predominated over the soluble form. This is shown by the data presented in figure 9. In Souvenir corms we also found an increase in the quantity of soluble nitrogen towards the end of storage with practically the same temperature response as with Giant Nymph. However, in Souvenir corms there was an increase in the insoluble nitrogen content during storage that was not found in Giant Nymph. An increase with the temperature is also shown, which indicates that the loss of moisture and the increased percentage of dry matter may be responsible for this change. It is of interest to note that Souvenir has a much larger nitrogen content than Giant Nymph. It is obvious that the C/N ratios of gladiolus varieties may differ considerably. These variations are reflected in the growth responses of the corms after planting and will be referred to in another section of this paper.
### TABLE IV

An analyses of Giant Nymph Corms Stored at 10°, 21° and 32° C.

Results Expressed as mg. per 100 gm. Green Sample

Sugars Calculated as d-glucose

1931-32

<table>
<thead>
<tr>
<th>Analysis</th>
<th>10° C.</th>
<th>21° C.</th>
<th>32° C.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reducing sugars</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>sugars</td>
<td>180</td>
<td>10</td>
<td>70</td>
</tr>
<tr>
<td>Non-reducing sugars</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>sugars</td>
<td>2060</td>
<td>3670</td>
<td>4920</td>
</tr>
<tr>
<td>Total sugars</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>sugars</td>
<td>2240</td>
<td>3680</td>
<td>4999</td>
</tr>
<tr>
<td>Starch</td>
<td>9616</td>
<td>7745</td>
<td>9263</td>
</tr>
<tr>
<td>Acid Hydrolyzable substances</td>
<td>389</td>
<td>321</td>
<td>664</td>
</tr>
<tr>
<td>Soluble</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>nitrogen</td>
<td>168</td>
<td>236</td>
<td>246</td>
</tr>
<tr>
<td>Insoluble</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>nitrogen</td>
<td>260</td>
<td>305</td>
<td>282</td>
</tr>
</tbody>
</table>
TABLE V
Analyses of Souvenir Corms Stored at 10°, 21° and 32° C.
Results Expressed as mg. per 100 gm. Green Sample
Sugars calculated as d-glucose

1931-32

<table>
<thead>
<tr>
<th>Analysis</th>
<th>10°C.</th>
<th>21°C.</th>
<th>32°C.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reducing sugars</td>
<td>327</td>
<td>80</td>
<td>170</td>
</tr>
<tr>
<td>Non-reducing sugars</td>
<td>2366</td>
<td>3094</td>
<td>3063</td>
</tr>
<tr>
<td>Total sugars</td>
<td>2693</td>
<td>3174</td>
<td>3233</td>
</tr>
<tr>
<td>Starch</td>
<td>13117</td>
<td>12164</td>
<td>12350</td>
</tr>
<tr>
<td>Acid hydrolyzable substances</td>
<td>423</td>
<td>724</td>
<td>1000</td>
</tr>
<tr>
<td>Soluble</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>nitrogen</td>
<td>219</td>
<td>197</td>
<td>240</td>
</tr>
<tr>
<td>Insoluble</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>nitrogen</td>
<td>503</td>
<td>559</td>
<td>575</td>
</tr>
</tbody>
</table>
REDUCING SUGARS
MGS. PER 100 GMS. GREEN SAMPLE
OF CORMS STORED AT 10°, 21°, AND 32°C.

Figure 6
Figure 7
Nitrogen
Mgs. per 100 gms. green sample
of corns stored at 10°, 21°, and 32°C.

Figure 8
Figure 9
3. MORPHOLOGY
Materials and Methods

In the fall of 1931, freshly harvested corms of Giant Nymph and Souvenir were stored at 10°C, 21°C and 32°C. Samples of buds from these corms were collected at monthly intervals throughout the storage period. On March 31, 1932 these corms were planted in the greenhouse and bud samples collected at weekly intervals until anthers and ovules were prominent in the flower. The buds were killed in formal acetic alcohol, imbedded in paraffin, sectioned and stained in "Fast Green" according to the standard technique for such material. Photomicrographs and drawings were made to show the important stages of development of the buds during storage and later of the flower spike.

Development of the Buds During Storage

The buds on gladiolus corms are evident at a very early stage in the development of the new corms. They increase in size during the growth of the plant in the field and are prominent at the time of harvest in the fall. A longitudinal section of a bud at harvest time is shown in plate III, fig. 1. The meristematic tip is enclosed by several leaf sheaths. At this stage the bud is entirely vegetative with no evidence of flower primordia. Apparently this is the resting condition of gladiolus buds during the major portion of the storage season. Watkins (36)
reports similar observations.

Samples of buds taken from corms stored at 10°, 21° and 32°C. showed no further anatomical advanced until February, when increased activity in leaf development was noted. This is illustrated in plate III, fig. 2. The leaf sheaths are more enlarged and the growing point is considerably broader. At the time of planting in the greenhouse in March the buds were still in this condition of increased leaf development with no visible evidence of flower differentiation.

The temperature at which the corms were stored had very little effect on the development of the buds during their dormant season. The buds at 32° and 21°C. became somewhat more elongated than buds at 10°C., especially with corms of Souvenir. It is of interest that the buds of Souvenir developed slightly in advance of the buds of Giant Nymph, doubtless a varietal characteristic.

Flower Differentiation

When the corms which had been stored at 10°, 21° and 32°C. were planted in the greenhouse in the latter part of March, the buds had started to swell and elongate, especially at 32°C., the first external evidence of increased activity caused by high storage temperatures. After planting, the effects of storage temperature became more pronounced, as is emphasized in table VI.
TABLE VI

Length of Shoots in Cms.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Periods of growth in weeks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Giant</td>
<td>:10°C: 1.0; 2.1; 5.0; 7.6;10.2;16.0;35.0;41.0;45.0</td>
</tr>
<tr>
<td>Nymph</td>
<td>:21°C;10.7;20.3;22.9;25.4;40.6;45.6;47.4;50.8;55.0</td>
</tr>
<tr>
<td></td>
<td>:32°C;13.0;27.9;30.1;33.0;50.8;60.8;73.8;80.6;87.0</td>
</tr>
<tr>
<td>Souvenir</td>
<td>:10°C; 2.5; 4.0; 5.7; 7.6;25.4;45.6;50.8;60.8;65.0</td>
</tr>
<tr>
<td></td>
<td>:21°C; 7.6;20.3;23.0;25.4;45.6;48.0;55.0;62.0;67.5</td>
</tr>
<tr>
<td></td>
<td>:32°C; 9.4;25.4;32.0;36.1;45.6;56.0;63.5;65.0;76.2</td>
</tr>
</tbody>
</table>

*Flower differentiation plainly evident

Samples of buds collected three weeks after planting showed no sign of flower differentiation. This period is characterized by extensive foliage development with a broadening of the meristematic tip.

The first traces of flower differentiation were found in samples collected four weeks after planting in the greenhouse. At this stage (plate III, figs. 4-5) the growing point is decidedly extended and lobing is very pronounced with evidences of the formation of a flower spike. As indicated in table VI, flower primordia were first evident in plants from corms which had been stored at 21°C and 32°C. The plants from corms exposed to 10°C did not show flower differentiation until several weeks later, with Souvenir three weeks in advance of Giant Nymph. It
is of interest that in all cases flower differentiation occurred after the formation of the new corm at the base of the stalk. In other words, flower primordia appear to arise from the new corm and are only indirectly associated with the mother corm. The data show no correlation between height of plant and flower differentiation.

The development of lobes and the extension of the flower spike continues over a period of two or three weeks, depending on the variety. Samples of the $21^\circ$ and $32^\circ$C. lots collected seven weeks after planting had well defined flower spikes with the individual flowers formed and anthers in the process of differentiation (plate III, fig. 6). The stamens of the gladiolus flower develop considerably in advance of the ovary. At this stage the flower spikes were visible to the naked eye. Eight weeks after planting the flower spikes had elongated and further differentiation of the individual flowers had occurred. The ovary had developed and contained numerous ovules in which megaspore mother cells were evident (plate IV, figs. 7 and 8). The anthers at this stage were filled with pollen (plate IV, figs. 10 and 11).

The history of development in the varieties studied was identical except that Souvenir produced its inflorescence slightly in advance of Giant Nymph. The differentiation of the floral tissue is accelerated considerably by high storage temperature.
Explanation: Plate III

Photomicrographs of longitudinal sections of gladiolus buds and flower spikes.

1. Condition of bud during major part of dormancy. X 30
2. Active leaf development takes place near the end of the storage period. X 30
3. The meristematic tip becomes broad and flat shortly after the corms are planted. X 50
4. First evidence of flower differentiation four weeks after planting. Definite lobing is evident. X 21
5. A late stage in the development of the flower spike, showing developing primordia of the individual flowers. X 21
6. Six weeks after planting the individual flowers are plainly evident with stamens well formed. X 19
Explanations: Plate IV

Photomicrographs of longitudinal and cross sections of gladiolus inflorescence and foliage.

7. Flower spike seven weeks after planting. The anthers are showing and the ovary is rapidly developing. X 9

8. Longitudinal section of ovary showing ovule arrangement with megaspore mother cells plainly evident. X 21

9. Cross section of young stem showing leaf arrangement and vascular bundles. X 21

10. Cross section of spike showing the main axis with flowers on opposite sides. The lower flower shows the anther arrangement. The pollen is nearly mature. X 21

11. Longitudinal section of the anthers containing pollen. X 21
Explanation: Figure 10

Drawings made with micro-projector.

1. Dormant bud. M, meristematic tip; L, leaf sheat. X 60

2. Bud showing active leaf development. X 60

3. The meristematic tip becomes broadened shortly after planting. X 60

4. Differentiation of the floral parts commences four weeks after planting. R, lobe; B, bract. X 25

5. Young flower spike. F, individual flower; D, secondary flower spike. X 15

6. Flower spike well differentiated with anthers and ovaries developed. X 15

7. Individual flower. A, stamen; P, perianth; G, carpel; K, outer spathe; I, inner spathe. X 60

8. Ovary with ovules attached to the placenta and megaspore mother cells well formed. O, ovule; Y, megaspore mother cell. X 15
4. GROWTH RESPONSES
Field Studies of Giant Nymph Corms Stored at 0°, 5° and 10°C.

1931

After the respiration studies were terminated on May 8 the corms were removed from the respiration chambers and planted in the field in fertile loam soil. These corms were grown with over-head irrigation and received the usual commercial culture. Records were taken on the various phases of growth, and these data are presented in table VII.

TABLE VII

Growth Responses

Giant Nymph Corms Stored at 0°, 5° and 10°C.

<table>
<thead>
<tr>
<th>Storage</th>
<th>No. of</th>
<th>Percent</th>
<th>Days</th>
<th>Total</th>
<th>No.</th>
<th>Wt. of</th>
</tr>
</thead>
<tbody>
<tr>
<td>temper-</td>
<td>corms</td>
<td>of corms</td>
<td>of corms</td>
<td>to</td>
<td>No. of</td>
<td>new</td>
</tr>
<tr>
<td>ature</td>
<td>planted</td>
<td>grew</td>
<td>flowered</td>
<td>bloom</td>
<td>spikes</td>
<td>corms</td>
</tr>
<tr>
<td>---------</td>
<td>---------</td>
<td>------</td>
<td>---------</td>
<td>------</td>
<td>-------</td>
<td>------</td>
</tr>
<tr>
<td>0°C.</td>
<td>141</td>
<td>90</td>
<td>82</td>
<td>109</td>
<td>105</td>
<td>140</td>
</tr>
<tr>
<td>0°C.</td>
<td>135</td>
<td>93</td>
<td>65</td>
<td>110</td>
<td>82</td>
<td>131</td>
</tr>
<tr>
<td>5°C.</td>
<td>145</td>
<td>97</td>
<td>93</td>
<td>103</td>
<td>133</td>
<td>139</td>
</tr>
<tr>
<td>5°C.</td>
<td>139</td>
<td>95</td>
<td>90</td>
<td>105</td>
<td>118</td>
<td>140</td>
</tr>
<tr>
<td>10°C.</td>
<td>148</td>
<td>100</td>
<td>89</td>
<td>98</td>
<td>147</td>
<td>200</td>
</tr>
<tr>
<td>10°C.</td>
<td>144</td>
<td>100</td>
<td>93</td>
<td>98</td>
<td>142</td>
<td>176</td>
</tr>
</tbody>
</table>

An analysis of this table shows that the percentage of corms which grew increased with the higher storage temperatures, which was also the case with the number of corms which produced flowers, the highest percentage of blind shoots occurring at 0°C. The
date of blooming was advanced as the storage temperature increased. Corms which had been stored at $10^\circ$C. produced the largest number of flower spikes and also a larger increase in new corms, but the number of cormels produced was inversely proportional to the storage temperature.

It appears that storage at $10^\circ$C. is superior to $5^\circ$ and $0^\circ$C., except in the matter of cormel development. Evidently the vigor of the plant is utilized either in the development of new corms, or else in the production of cormels. The quality and size of the flower spikes produced from the corms stored at $0^\circ$, $5^\circ$ and $10^\circ$C. were practically the same.

Since storage at $10^\circ$C. had given superior growth response, the question arose whether storage at still higher temperatures might show further advantages. Preliminary experiments with corms stored at $32^\circ$ C. showed marked results in favor of higher temperatures. Loomis and Evans (27) found that the blooming date was advanced four weeks by exposing corms to a storage temperature of $102^\circ$F. for two weeks. Pridham (32) and Floyd (11) report stimulated growth response from corms stored at temperatures above $40^\circ$F. Denny (10) states that corms stored at $30^\circ$C. for a period of three weeks made very satisfactory growth, and the results were often superior to those from corms treated with ethylene chlorhydrin to break the rest period. With these facts in mind experiments with higher storage temperatures were conducted in 1931-32.
Greenhouse Studies of Giant Nymph and Souvenir Corms Stored at 10°, 21° and 32° C.

1932

The respiration studies of 1931-32 were terminated February 8, and the corms planted in the greenhouse in compost soil. They received the usual greenhouse culture under uniform conditions with full sunlight, abundant moisture and a day temperature of 21° C. with 12° C. at night. As the season progressed the days became warmer, and the temperature in the greenhouse increased proportionately. In June the high temperature under glass retarded the normal development of the 10° and 21° C. corms of Giant Nymph. This will be referred to in a later paragraph.

Records were taken on the growth response and these data are presented in table VIII. Attention is called to the fact that these figures are relevant to forcing conditions in the greenhouse and are not directly comparable to growth in the field.
### TABLE VIII

**Growth Responses**

Giant Nymph and Souvenir Corms Stored at 10°, 21° and 32°C.

1932

<table>
<thead>
<tr>
<th>Storage Treatment</th>
<th>No. of Corms</th>
<th>Percent of Corms</th>
<th>No. of Corms</th>
<th>Percent of Corms</th>
<th>No. of Corms</th>
<th>Percent of Corms</th>
<th>No. of Corms</th>
<th>Percent of Corms</th>
<th>No. of Corms</th>
<th>Quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Giant Nymph - 10°C</td>
<td>58</td>
<td>100</td>
<td>93</td>
<td>4</td>
<td>67</td>
<td>3</td>
<td>130</td>
<td>poor</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Giant Nymph - 21°C</td>
<td>80</td>
<td>95</td>
<td>75</td>
<td>16</td>
<td>34</td>
<td>2</td>
<td>126</td>
<td>poor</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Giant Nymph - 32°C</td>
<td>61</td>
<td>87</td>
<td>96</td>
<td>2</td>
<td>58</td>
<td>9</td>
<td>91</td>
<td>excellent</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Souvenir - 10°C</td>
<td>89</td>
<td>94</td>
<td>96</td>
<td>3</td>
<td>148</td>
<td>8</td>
<td>110</td>
<td>medium</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Souvenir - 21°C</td>
<td>82</td>
<td>95</td>
<td>94</td>
<td>4</td>
<td>130</td>
<td>9</td>
<td>96</td>
<td>medium</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Souvenir - 32°C</td>
<td>79</td>
<td>96</td>
<td>89</td>
<td>13</td>
<td>83</td>
<td>8</td>
<td>86</td>
<td>excellent</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The data in table VIII show that the percentage of Giant Nymph corms that grew decreased as the storage temperature increased. With Souvenir corms this situation is reversed. Although the proportion of Giant Nymph corms that flowered did not consistently increase with the storage temperature, more flowers were obtained from the corms stored at 32°C. than from those stored at 10°C. With Souvenir the percentage of corms that flowered decreased with higher storage temperatures. Lower storage temperatures promoted flower production but the quality of the spikes declined. The corms stored at higher temperatures bloomed much earlier than corms stored at lower temperatures.

Giant Nymph from 32°C and 21°C. produced one spike per corm, but from the 10°C. stock two spikes per corm were common. There was no variation of this nature with Souvenir. Corms of this variety produced two and three spikes regardless of storage temperature. The general growth from corms stored at higher temperatures was more rapid, and in the majority of cases superior, especially with Giant Nymph. The spikes of Giant Nymph were larger and averaged twelve flowers per spike as compared to ten flowers or less for the lower temperatures. This inferior development at 10°C and 21°C. is in part attributed to the high temperatures in the greenhouse during June, when the flower spikes and foliage of Giant Nymph were decidedly dwarfed and otherwise unsatisfactory. In all cases the first crop of flowers was far superior to the spikes produced in the
prolonged period of blooming that followed.

Plates V and VI are typical of the variations in the growth response of corms which had been stored at 10°, 21° and 32° C. The photograph of Giant Nymph (plate V) was taken May 3, 83 days after planting the corms in the bench. The photograph of Souvenir (plate VI) was taken 79 days after planting. In the case of Souvenir the 10°, and 21° C. stock continued to develop until it finally attained the size of the 32° C. plant shown in the photograph. The 10°, and 21° C. stock of Giant Nymph, however, remained inferior throughout the entire growing period.
Explanation: Plate V

Observations left to right -

1. Giant Nymph with 10°C. storage
2. Giant Nymph with 21°C. storage
3. Giant Nymph with 32°C. storage

Photograph taken 83 days after planting in the greenhouse.
Explanation: Plate VI

Observations left to right -
1. Souvenir with 10°C. storage
2. Souvenir with 21°C. storage
3. Souvenir with 32°C. storage

Photograph taken 79 days after planting in the greenhouse.
Plate VI
DISCUSSION

Gladiolus corms respire slowly during their dormant season, and moderate fluctuations in the storage temperature apparently have a very limited effect on the physiological activity of the corms. It is of interest to note that the temperature in many of the large commercial gladiolus storage houses varies 10° to 15°F, apparently without producing any ill effects on the subsequent growth of the corms in the field. The most rapid changes in the corms occur during the curing process when large quantities of moisture are lost. The nature and significance of the changes which occur during this period provide material for further investigation.

The rate of respiration varied for the two varieties studied. Souvenir, a variety which matures early, respired more rapidly than Giant Nymph, which matures comparatively late. It may be that early maturity is associated with high respiratory rate, and if this is true, the storage of early varieties should receive special attention. Thus it would appear that varieties which mature early would be benefited by moderately low storage temperatures to reduce the combustion of reserve carbohydrates and proteins which are utilized by the plant in the early stages of growth. On the other hand, varieties which mature late may be stored at higher tempera-
tures to increase the respiration rate and materially shorten the dormant period. Although temperature and moisture content are probably the most important factors in the respiration of gladiolus corms, still the existence of other factors which are at times decisive is indicated by the fluctuations which are common in the respiratory intensity at all temperatures.

A considerable variation was found in the chemical composition of the corms at different periods during the storage season. These variations occurred mostly in the carbohydrate fractions, especially reducing and non-reducing sugars. If reducing sugars are to be considered the immediate source of respiratory material, then a partial explanation of the accumulation of sugars at low temperature may be found in the reduced respiration under these conditions. No general correlation between the sugar content and respiration at high temperatures was evident. Hasselbring and Hawkins report similar results with sweet potatoes. The nitrogen content of the corms remained rather constant throughout the storage season. With such an abundance of starch present, proteins would not ordinarily be used in respiration and apparently other processes which might involve protein hydrolysis were not important.

Temperature has very little effect on the development of the buds throughout their normal storage season. During this period the buds are in a vegetative condition with no visible evidence of flower primordia. However, it is reasonable to
believe that certain changes do occur which prepare the bud for subsequent growth, a probability that is emphasized by the wide variations in the development of the buds after planting. A chemical analysis of the buds after exposing the corms to various storage temperatures would be highly desirable and might aid in the explanation of the subsequent bud development. Since flower differentiation occurs soon after planting, it is very essential that the corms have ideal growing conditions at this time; otherwise the normal formation of the flower spike may be inhibited or entirely prevented, resulting in partial or complete "blindness" of the plant. Conditions which retard the normal growth of the plant have a similar effect on the development of the flower spike. The formation of the inflorescence extends over a period of several weeks and differentiation of the individual flowers is completed by the time the flower spike emerges from the inner leaf. Differentiation of the floral parts and the extension of the spike are greatly accelerated by high storage temperatures, a very desirable reaction from the standpoint of early forcing of gladiolus in the greenhouse.

Striking variations occurred in the growth of corms which had been stored at various temperatures. In the field the 10°C. stock proved to be superior to 5°C. and 0°C., while in the greenhouse the advantages of 32°C. storage were decisive. The plants shown in plates V and VI illustrate the responses shown to the different storage temperatures. The high storage
temperature favors rapid maturity and more vigorous inflorescence. The warm temperature storage treatment evidently aids in breaking the rest period and in getting the buds into condition to grow. High respiratory intensity is obviously associated with this increased activity, and probably the accumulation of total sugars, although a definite correlation is lacking in some cases. Important changes may take place in the buds, and the chemical composition of the corm as a whole may be indirectly related to these processes.

If the storage period is prolonged in the spring, the advantages of the high temperature treatment are somewhat curtailed; therefore this procedure is more valuable in the case of corms forced in the greenhouse. Gladiolus corms from the west coast have been used extensively for extra-early forcing in the greenhouse, but if this high temperature storage treatment can be applied to the ordinary field grown corms of Iowa, the purchase of high-crowned, early-harvested stock from California should be unnecessary.

Although the data in this experiment show superior results from corms stored at 32°C., further investigation is needed on warm temperature treatment with special reference to the length of time the corms should be exposed to the high storage temperature. It is entirely possible that storage at low temperatures during the major portion of the dormant season, followed by a few weeks exposure to high temperatures, would be as effective
as continuous storage at 32°C. Storage at high temperatures, followed by several weeks exposure to low temperatures, should also be investigated. By this method it is possible that a certain combination of storage temperatures for the corms could be found that would greatly improve the general growth of the gladiolus plant.
SUMMARY

Respiration

Uniform samples of gladiolus corms were stored at constant temperatures of 0°, 5°, 10°, 21° and 32°C. Respective respiration rates were determined at frequent intervals throughout the storage season by measuring the quantity of carbon dioxide evolved from a known weight of corms.

1. The respiratory intensity decreases rapidly during the first four weeks of storage and then diminishes more gradually with decided fluctuations occurring at certain periods.

2. Souvenir corms respired more rapidly than Giant Nymph corms.

3. Factors other than temperature appear at times to be decisive in the physiological behavior of gladiolus corms in storage.

4. Extensive shrinkage occurs in corms during storage.

5. There appears to be a positive correlation between respiration intensity and the moisture content of the corms.

Carbohydrate-Nitrogen Analysis

Samples of the corms for carbohydrate-nitrogen analyses were taken at the beginning, the middle and at the end of the storage period, and the following chemical relationships observed:
1. Sugars accumulate in gladiolus corms during the dormant season, especially at 0°C.
2. The quantity of reducing sugar in gladiolus corms is very limited and decreases as the storage temperature rises.
3. The starch content of corms is high, varying from 9 to 14 percent of the fresh weight for the varieties used.
4. The starch content decreases slightly during storage.
5. The acid hydrolyzable substances increase during storage because of the loss of moisture and the consequent increase in the percentage of dry matter.
6. The nitrogen content remains nearly constant during storage at low temperatures. At high temperatures the soluble nitrogen increases, but the insoluble fractions remain more constant.
7. The C/N ratio varies with different varieties.

Morphology

Samples of buds from corms stored at 10°, 21° and 32°C. were collected at monthly intervals throughout the dormant period and preserved in killing fluid. In March the stored corms were planted in the greenhouse and bud samples collected at weekly intervals until anthers and ovules were prominent in the flower. Stained serial sections show that:

1. Vegetative buds are prominent early in the development of the new corm and remain in this condition during the major
part of storage, with active leaf development toward the end of the rest period.

2. Differentiation of flower primordia in Giant Nymph and Souvenir does not occur until three to four weeks after planting.

3. The plants from corms previously stored at high temperatures developed more rapidly and differentiation of the floral parts is correspondingly accelerated.

4. Flower primordia arise from the new corm and appear to be only indirectly associated with the mother corm.

5. The history of development in the varieties studied was identical except that Souvenir produced inflorescence slightly in advance of Giant Nymph.

Growth Response

After the respiration studies were terminated in 1931 the corms were removed from the respiration chambers and planted in the field. In 1932 the corms were removed from the respiration chambers at an earlier date and forced in the greenhouse. Records were taken on the various phases of growth.

1. Storage of gladiolus corms at temperatures below 5°C. was not satisfactory.

2. The most striking results were obtained from corms stored at 32°C. and forced in the greenhouse. The growth response at this temperature was far superior to the responses
was more pronounced than with \textit{Souvante}.

6. The response of Giant Nymph to high storage temperature

ment of corals.

increase in new corals, while low temperatures favor the development of corals stored at high temperatures produced the largest.

The Greenhouse.

either used to a marked degree, especially with corals stored in

4. High storage temperature hastened maturation of the corals

storage temperature, especially with Giant Nymph.

2. The quantity of broom increased with a rise in the

from corals stored at the lower temperatures.
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