EFFECT OF BULB STORAGE TEMPERATURE AND PLANTING DATE ON DEVELOPMENT OF GARDEN-GROWN TULIPS, HYACINTHS AND DAFFODILS

By

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CHAPTER I

INTRODUCTION

Tulips (*Tulipa* hybrids), hyacinths (*Hyacinthus orientalis*) and daffodils (*Narcissus* hybrids) have long been included in the beautiful displays of spring-flowering bulbs in Oklahoma gardens. Bulbs from Holland (8) and the U.S. (2,17) are offered for sale starting in September and continuing until supplies are depleted by "special sales" at reduced prices in January.

Recommendations for Oklahoma (26,20) relative to planting dates and other cultural procedures have largely followed those given for more northerly locations (20), or have been derived over a long period of time through grower observations. Bulbs for fall planting are usually held until sale in open display bins at "room temperature" in garden centers or other retail outlets (6,4).

To our knowledge, no formal research has been conducted in Oklahoma to determine optimum planting dates for various species or to investigate the effects of various bulb handling methods.

As a pilot study, an experiment with tulips, hyacinths and daffodils was designed to investigate effects of planting dates and warm and cold storage of bulbs prior to

planting. Specific objectives were:

1. To determine optimum bulb planting date(s) between September 27 - January 3 for 'Flying Dutchman' tulip, 'Blue Jacket' hyacinth and 'Carlton' daffodil to aid in making future recommendations for Oklahoma.
2. And to, compare the effects of warm 18-20°C (65-68°F) versus cool 7°C (45°F) bulb storage temperatures before planting, for these 3 species, on garden performance of the plants in the spring.

CHAPTER II

REVIEW OF LITERATURE

Early History and Classification

Most species of bulbs and corms are found in the Middle-east and Southeastern Europe (14). The most popular flowering bulbs grow in the surrounding countries such as Greece, Bulgaria, Syria, Lebanon, Iran, Afghanistan and other neighboring countries. Bulbs from these areas were the first to come to the Western World. Possibly the first ones were brought to Britain with the Romans. By the middle of the fourteenth century, bulbs were being imported into Britain and Western Europe from the Near East (14).

History tells up Pharaohs grew daffodils, ancient Egyptians used them in funeral wreaths, and a mid-fifteenth century manuscript gave evidence of their use in English gardens (11). Even Theophrastus (a philosopher and pupil of Aristotle) referred to daffodils 300 years before Christ (11).

Dioscorides in his great work on medicinal plants in the first century A.D. spoke of hyacinths. The Empress Josephine as well, cherished varieties of the common hyacinth in the garden at Malmaison (10).

The most fascinating stories, however, were told of the tulip which first came to Europe in the sixteenth century from Turkey. The tulip from Northern Iran was seen by Busbecq, Ferdinand I's ambassador to Constantinople, in 1554. He sent these bulbs to Vienna and Prague sending information that the Turks sold these bulbs for large sums. The blooms very closely resembled the Eastern turban giving them added popularity (14).

"Carolus Clusius, a famous botanist was probably the first man to import and introduce the Tulip to the botanical gardens at Leiden, Holland. It was described as a very rare flower and soon afterwards the Tulip began to appear in royal gardens of the various European Kings and Emperors." (8).

By 1634 a tulip craze called "Tulipomania" hit Holland and lasted for 3 years. Tulips became the "greatest vogue of the day" as well as the object of wild speculation. Stories were told that some tulips cost as much as a merchant ship and that 2 houses in Amsterdam were sold to pay for 3 tulip bulbs. But the craze came to a crash in 1637 leaving many speculators bankrupt (14,12).

Most tulips are the result of extensive breeding and selection. It is thought that they had their origin in Tulipa Gesnerana, or in some cases, in the dwarf Tulipa suaveolens of southern Russia (18). In addition to these complex hybrids, there are many tulip species.

According to "Hortus Third" (18)

The Classified List, revised 1971, uses the following scheme for the classification of cultivated tulips:

Early

1. SINGLE EARLY TULIPS.
2. DOUBLE EARLY TULIPS.

Midseason

3. MENDEL TULIPS. Chiefly the result of crosses between the old Duc van Tol and Darwin Tulips. Single; plants seldom more than 20 in. high.

4. TRIUMPH TULIPS. Chiefly the result of crosses between Single Early Tulips and Late (May-flowering) Tulips. Single; plants generally of stouter build than Mendel Tulips and seldom more than 20 in. high.

5. DARWIN HYBRID TULIPS. Chiefly the result of crossing Darwin Tulips with Tulipa Fosterana and the result of crossing other tulips with tulip species when the offspring have the same habit and show little evidence of the wild species; single.

Late or May-flowering

6. DARWIN TULIPS. Single; tall; lower part of flower usually rectangular in outline.

7. LILY-FLOWERED TULIPS. Single; flowers with pointed, reflexed segments.

8. COTTAGE TULIPS (SINGLE LATE TULIPS). Tulips which do not belong to division 6 or 7. Single; flowers often long or egg-shaped.

9. REMBRANDT TULIPS. Broken Tulips, striped or marked brown, bronze, black, red, pink, or purple on red, white, or yellow ground.

10. PARROT TULIPS. Tulips with laciniate petals.

11. DOUBLE LATE TULIPS (PEONY-FLOWERED TULIPS).

Species (Wild plants and their cultivars, and those hybrids in which the wild plant is evident.)

12. KAUFMANNIANA, varieties and hybrids. Very early-flowering, sometimes with mottled foliage.

13. FOSTERANA, varieties and hybrids. Large, early-flowering, sometimes with mottled or striped foliage.

14. GREIGII, varieties and hybrids. Flowering later than Kaufmanniana Tulips, always with mottled or striped foliage.

15. OTHER SPECIES, and their varieties and hybrids.

> Cultivar names of tulips may be found in the latest edition of the Classified List and International Register of Tulip Names, an alphabetical listing of all names that have been published for cultivated tulips, including specific epithets as well as cultivar names, and synonyms of those (p. 1132).

Hyacinthus orientalis L., the Dutch, Common or Garden Hyacinth, found in North Africa, Greece to Asia Minor and Syria, is widely cultivated as a garden plant and in southern France as a source of perfume (18).

The hyacinth was discovered about the same time as tulips, but was not prominent for many years because the flowers were not very attractive. After much hybridizing and improvement, better cultivars were developed and commercial interest grew. The hyacinth became a top classic, "fashion" flower with outstanding colors and fragrance (8).

Daffodils are native to Europe and North Africa (18). England and Holland helped to develop better cultivars through the years. About 100 years ago, the Poetaz (Cluster Narcissus) were in greatest demand, while today the Daffodils (large trumpet Narcissi), the large and small cupped Narcissi, double and some Poetaz cultivars are most popular (8).

According to "Hortus Third" (18)

> Effective Jan. 1, 1950, a revised system for the horticultural classification of daffodils was adopted by the Royal Horticultural Society (Daffodil and Tulip Year Book 1948, pp. 101-103) in which the LEEDSII, BARRII, and INCOMPARABILIS groups were abandoned and incorporated into categories based on flower proportions, with further

subdivision based on color combinations. Eleven divisions are now recognized as follows, all except no. 10 of garden origin:

1. TRUMPET NARCISSI. Fl. 1, corona as long as segms. or longer.
2. LARGE-CUPPED NARCISSI. Fl. 1, corona 1/3 to nearly as long as segms.; of N. X incomparabilis origin.
3. SMALL-CUPPED NARCISSI. Fl. 1, corona less than 1/3 as long as segms.; of N. X incomparabilis origin.
4. DOUBLE NARCISSI.
5. TRIANDRUS NARCISSI. Characteristics of N. triandrus clearly evident.
6. CYCLAMINEUS NARCISSI. Characteristics of N. cyclamineus clearly evident.
7. JONQUILLA NARCISSI. Characteristics of any of the N. Jonquilla group (Section Jonquilleae) clearly evident.
8. TAZETTA NARCISSI. Characteristics of any of the N. Tazetta group (Section Hermione) clearly evident.
9. POETICUS NARCISSI. Characteristics of the N. poeticus group (Section Narcissus) clearly evident.
10. SPECIES AND WILD FORMS AND /WILD/ HYBRIDS.
11. MISCELLANEOUS NARCISSI not referable to other groups (p. 754).

Stages in Production of Spring Flowering Bulbs

As background information for bulb forcers, August De Hertogh, in "Holland Bulb Forcer's Guide" (6) presented five important stages in the production of spring flowering bulbs. These stages are very applicable to garden-grown bulbs as well, and are presented below:

1. the harvesting and preplanting dry storage of bulbs,
2. the planting, rooting and low temperature mobilization,
3. flower stalk elongation,

4. flowering,

5. subsequent increases in bulb size (pp. 1, 3).

De Hertogh (6) stated:

> In practice, these stages occur as follows: Initially, all bulbs are harvested in June, July or August. They are graded according to circumference measurements and stored at warm temperatures to fully develop the floral organs (Author's note--this is particularly significant--to realize that when the garden centers receive the bulbs in September and display them for sale, the flower buds are already present and developing in the bulb). In the fall, the bulbs are planted, kept moist by the rains, rooted, and over wintered at low temperatures to mobilize the plant for flowering and bulbing. In the spring, after the cold requirement has been satisfied, the floral stalk elongates and the plant flowers. For some species, e.g. tulips, the flowers are removed at this point to aid in increasing the size of the bulbs. For most of the bulbs, the largest increase in bulb size takes place from the time of flowering to the time of harvesting.
>
> If bulbs are closely observed during this cycle, it can be seen that the bulbs are never dormant. They are continuously developing and monitoring their environment and act much as 'Biocomputers' (p. 3).

Storage Temperatures

Much research has been done on the temperatures for storing of hyacinths, daffodils and tulips; yet, most is in relation to forcing. This creates some confusion reading the current literature because the researcher often stored a group of bulbs at 2 or 3 different temperatures in succession before planting.

Timmer (27) reported that storing at 25.5-30°C (77.9-86°F) caused later flowering and that storing at 17-20°C (62.6-68°F) caused earlier flowering. He generalized

by saying the total yield of bulbs was highest after high temperature storing. Aoba and Shibya (1) stored tulips for 2-3 months at 2 different temperatures, then planted them in a box at 17°C (77.9°F) on September 20 or October 20. Their results were as follows: Those bulbs stored at 5°C (41°F) and 0°C (32°F) sprouted earlier, shoots grew normally and large bulbs were produced. The bulbs stored at 15°C (59°F) produced stunted plants, no daughter bulbs and delayed sprouting. Their conclusion was that the stunting or physiological dwarfing caused by dormancy would be broken by sufficient chilling. Moe and Wickstrom (21) stored tulip bulbs at 5°C (41°F) and 21°C (69.8°F). The rate of shoot growth and the percentage of flowering bulbs increased as the length of time in the 5°C (41°F) storage increased. Bulbs stored for 6 weeks or less at 5°C (41°F) had many non-flowering bulbs and slower shoot elongation when there were flowers. This was also found to be true for those bulbs stored at 21°C (69.8°F). Storage time was for 2, 4, 6, 8, 12, and 14 weeks for both temperatures. In another experiment, Moe (22) precooled tulip bulbs at 5°C (41°F) for 3, 6, 9, 12 and 15 weeks, and then forced them at 18°C (64.4°F). His results showed that increasing the number of weeks of cold treatment promoted shoot elongation. Those bulbs that had the longest shoots at flowering had been precooled for 12-15 weeks. Along with this, flowering occurred earlier and the percentage of flowers increased after increasing weeks of precooling. The flower quality also improved.

In working with bulbs to be planted outdoors, Dickey (7, p. 461) of Florida considered "the effects of the duration and temperature of the cold treatment and the storage time, and of temperature before and after cold treatment" on tulip bulbs. He did several experiments involving different storage times and temperatures. He used bulbs of the Darwin group varieties, The Bishop, Scarlett Leader, Clara Butt, City of Harlem, William Copeland and Inglescombe Yellow and found that when these bulbs were cold-treated, "they grew and flowered well when planted outdoors in northern and central Florida."

Gill et al. (15) of Georgia did several tests on tulips using different combinations of storage temperatures ranging from 4-18°C (40-65°F) and storage times of 4 through 8 weeks. They found that precooling at 4°C (40°F) produced longer stems and earlier bloom dates. Without cool storage the stems were shorter and bloom dates were later. Gill et al. (15) summarized by saying "satisfactory tulips were obtained when the bulbs were precooled for at least six weeks at 4°C (40°F) and planted in December and January" (p. 459).

Charles-Edwards and Rees (3) explained:

> A period of cold is a common requirement for the normal development of many annual, biennial and perennial plants from Mediterranean and Temperate regions. Although little is known of the mechanisms of the cold requirement phenomena, a common feature amongst plants with storage organs is that polysaccharide to sugar conversions are enhanced at low temperatures. The high soluable sugar content at these low temperatures protects the organ from frost damage, whilst the cold requirement itself prevents the plant from growing

in the autumn, when severe weather might later cause the death of the shoot (p. 401).

Recommendations for Home Gardeners or Commercial Retail Outlets That Sell Bulbs

Many recommendations are made to the home gardener from various gardening magazines, but little or no formal research is cited. There is much literature and research on temperatures for storage, but most is related to forcing these bulbs.

According to the "Holland Bulb Garden Guide" (7) when bulbs are received they should be stored dry and well ventilated. In general bulbs may be stored in temperatures of 17-20°C (63-68°F). A. A. De Hertogh (4) recommended storing at slightly cooler temperatures if those recommended cannot be attained. Bulbs should be handled with care and not stored near ethylene-producing materials such as fruits.

The planting site should be well-drained and fertile (5). When planting, incorporate a high phosphate and potassium fertilizer into the soil (5). If the soil is low in organic matter the home gardener may want to add peat, pine bark or compost (4). Space bulbs approximately 10.3-15.4 cm (4-6 in) apart (7,15). Commonly, the home gardener is encoraged to plant hyacinths 10.3 cm (4 in) deep; tulips, 15.4-17.9 cm (6-7 in); and daffodils, 15.4-20.5 cm (6-8 in), or more generally, small sized bulbs (2.6 cm (1 in)) should be 12.8 cm (5 in) deep to the base and large sized bulbs

(5.1 cm (2 in) more) 20.3 cm (8 in) deep (28). These planting depths are to help protect bulbs from animals, frost and damage due to hoeing, etc. (4). Cover bulbs with only one-half of the soil removed in digging the hole. Water thoroughly and cover bulbs with the remaining soil. The entire bed should be watered thoroughly after planting. Then, may cover with a mulch such as compost or wood chips. If the fall is dry, periodic watering may be needed. In the spring the bulb area can be fertilized again. Once flowers have died remove these, but leave the foliage until it dies naturally. If foliage is cut too early the bulb will not have time to regenerate itself. Harvesting or splitting of the bulbs is not encouraged (4,5).

A. A. De Hertogh recommended planting September through October in zones 4 and 5, October through November in zones 6 and 7, and November through December in zones 8 and 9. Stillwater, Oklahoma, is in zone 7 (30). Others suggested that tulips in Northern regions, because of their need for a period of cold and darkness to bloom, should be planted in the fall before the ground freezes (13). Laurie and Ries (19) recommended that daffodils be planted before the ground freezes or by mid-December and that tulips and hyacinths could also be planted as late as mid-December. In Ohio (20) daffodils were planted from July to January. A late September planting date was considered optimum. Tulips were planted from October through mid-December and late October through November was considered the best dates for planting.

In Southern regions where the winter temperatures were warmer tulips were treated as annuals (13). Sunset's Menlo Park Gardens planted in October and November. However, they suggested that in warm-winter climates not to plant until December, meanwhile chill tulips and hyacinths at 4-7°C (40-45°F) in the refrigerator (29). Another source encouraged planting anytime from mid-September through November depending on the frost dates, or bulbs can be planted later if the ground has not frozen (16). Others advised planting daffodils in September or October and other spring flowering bulbs as early as they could be obtained in the fall (12). It is evident that the home gardener is besieged with suggested planting dates that extend from September through January. In Oklahoma the home gardener may be encouraged simply to plant bulbs in the fall or more specifically to plant tulip bulbs in November and December (9,26). But, there is apparently little formal research data available to reinforce such recommendations.

CHAPTER III

METHODS AND MATERIALS

Bulbs

Research was conducted at the site of the Oklahoma State University Research Greenhouses in Stillwater, Oklahoma (36°9' N Latitude, 97°5' N Longitude). On May 25, 1982, spring flowering bulbs imported from Holland[1] were ordered in the following quantities:

500 12 cm and up 'Flying Dutchman' tulips (Darwin hybrid)

600 DN #1 'Carlton' Narcissi (large cup Narcissus)

540 18-19 cm 'Blue Jacket' hyacinths

Bulbs arrived September 17 in well ventilated, heavy plastic crates. Until September 27 all bulbs were held in their crates at room temperature. (This was in a room in the headhouse of the Research Greenhouses.) On September 27, each species was divided into two equal groups of bulbs. One-half was stored at room temperature at 18-20°C and the other one-half was stored at 7°C in a refrigerated cooler in ventilated trays on shelves.

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[1] De Vroomen Export b.v. (wholesale bulbgrowers and exporters of Sassemheim, Holland), P.O. Box 808, Roswell Georgia 30077.

Experimental Treatments

An experiment was designed to include 16 treatments consisting of 8 planting dates spaced 2 weeks apart, from September 27 through January 3, and 2 bulb storage temperatures, 18-20°C and 7°C. Treatments are listed below:

Treatments	Planting Dates	Storage Temperatures
1	September 27	(planted September 27)
2	September 27	(planted September 27)
3	October 11	18-20°C
4	October 11	7°C
5	October 25	18-20°C
6	October 25	7°C
7	November 8	18-20°C
8	November 8	7°C
9	November 22	18-20°C
10	November 22	7°C
11	December 6	18-20°C
12	December 6	7°C
13	December 20	18-20°C
14	December 20	7°C
15	January 3	18-20°C
16	January 3	7°C

Experimental Design

A randomized complete block design was used. There were 3 replications of tulip, 3 replications of hyacinth, 4 replications of daffodil and 7 bulbs per replication.

Physical Arrangement and Bed Preparation

Two beds were prepared between each set of research greenhouses and oriented north and south (Figure 1). Each bed contained 2 different species. A buffer row of bulbs was planted at the north and south end of each bed with 7 bulbs in each buffer row. Because of the shading of the greenhouses, no more than 2 replications for each species were planted in west beds and no more than 2 replications for each species were planted in east beds. Thus, one species was not always planted in a west bed or in an east bed. Each bed was 0.6 m (2 ft) from the greenhouse with a 1.5 m (5 ft) space between the beds themselves.

Six beds 1.5 x 8 m (5 x 26 ft) were prepared for this project. Beginning July 21 each bed was sprayed with Roundup at a 3% rate (240 ml/3.785 l). Then each bed was roto-tilled 4 times and grass and weeds were removed. Beds were improved by addition of sandy top soil, a 2.6 cm (1 in) layer of peat, perlite and vermiculite and a 1.3 cm ($\frac{1}{2}$ in) layer of sterilized cattle manure. The beds were then roto-tilled. Just before planting 0.68 kg/9.3 sq m ($1\frac{1}{2}$ lbs/100 sq ft) of 10-20-10 (10-8.8-8.3) fertilizer

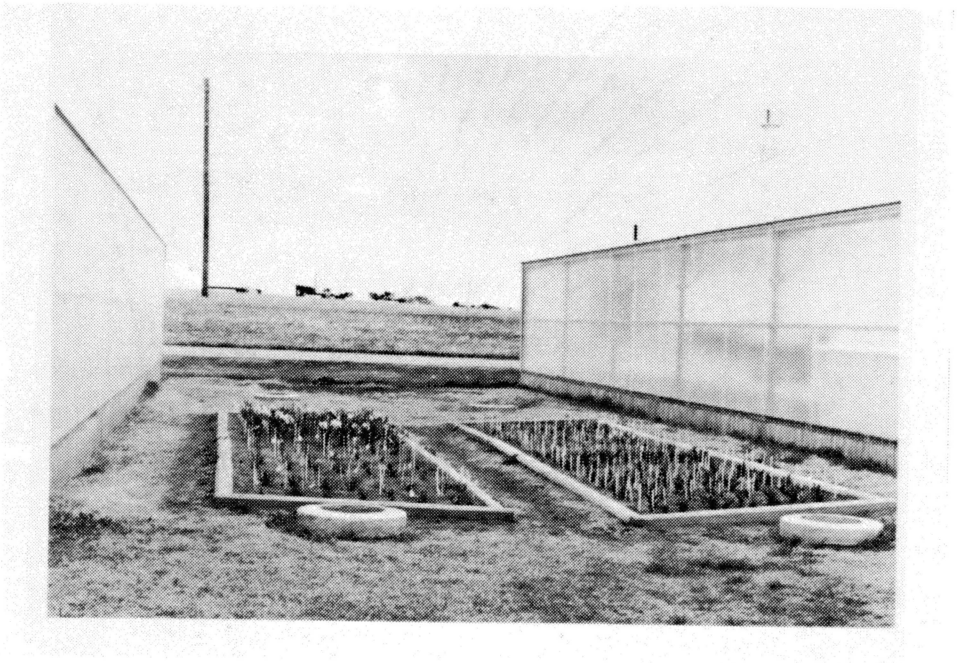

Figure 1. Bed Orientation (North-South)

was incorporated into each bed. Landscape timbers were used to build borders for all 6 beds.

September 20 all 6 beds were chemically sterilized using Brom-O-Gas (98% methyl bromide and 2% chloropicrin). Three cans (1 can = 0.45 kg (1 lb)) were applied to each bed according to the manufacturer's recommendations. Each bed was covered with a heavy clear plastic and sealed around the edges with sand, prior to release of the sterilant. These beds remained covered for 24 hours. After the plastic was removed, the beds were allowed to air 6 days before planting began September 27.

Planting and Culture

Bulb plantings were spaced 15 x 20 cm (6 x 8 in). Tulips were planted 15 cm (6 in) deep to the top of the bulb; hyacinths, 14-15 cm (5.5-6 in) to the top of the bulb; and daffodils, 11-14 cm (4-5.5 in) to the top of the bulb. Each hole was dug to the proper depth. Some of the soil removed was placed in the bottom of the hole. The bulb was then placed firmly in the hole and covered with some of the soil, filling the hole one-half way. Each bulb was watered and the hole was filled with soil the rest of the way. Again the hole was watered thoroughly. When each bed was completed the soil was raked for a level surface. As needed, supplemental irrigation was used through October.

Data Recorded

1. Emergence date.
2. Date of first visible bud.
3. Flowering date.
4. Number of flowers for daffodils.
5. Final plant height.
6. Useable life of the first flower (the number of days and last useable date).
7. Number of leaves.
8. Average height of leaves (average leaf length from the ground up).
9. Dimensions of flower - The first day a flower opened 3 measurements were taken:
    1. Daffodil trumpet, tulip cup, and hyacinth spike length.
    2. The diameter of each.
    3. The height of the flower from the ground to the top of the flower.
10. Top dry weight - The above-ground plant parts of tulips, hyacinths and daffodils were placed in paper sacks and dried in an oven. Tulips and hyacinths were dried at $57^{\circ}C$ ($135^{\circ}F$) for 24 hours. Daffodils were dried at $75 \pm 5^{\circ}C$ ($170^{\circ}F$) for 72 hours. After the plants were weighed, the weight of the paper sack was subtracted from the combined weight of the plant and the paper sack to give the top dry weight of the plant.

CHAPTER IV

RESULTS AND DISCUSSION

Tulips, hyacinths and daffodils will be discussed separately. Each species was analyzed as a separate experiment.

Tulip

Emergence dates for tulips indicated that bulbs stored at 7°C before planting, emerged significantly earlier than bulbs stored warm (Table I, Figure 2). This significance occurred after 4 through 14 weeks of storage. Bulbs stored at 7°C emerged, on the average, 18 days earlier than those stored at 18-20°C. Dickey (7) also found this to be true when he stored 'Bishop' and 'Scarlett Leader' bulbs ("first size" bulbs of the Darwin group cultivars) at 14°C (37°F) and 6°C (43°F) for 52 days. He stated they "emerged sooner and grew more vigorously than those stored at these temperatures for 26 days or than bulbs given no cold storage" (p. 462).

For bulbs stored at 18-20°C, the later the planting date, the later the emergence date (Table I, Figure 2). Charles-Edwards and Rees (3) stated

> In the tulip there is a low-temperature requirement after the completion of flower

TABLE I

SIGNIFICANCE OF MAIN EFFECTS AND INTERACTIONS - TULIPS

Source of Variation	Emergence Date	Date of 1st Visible Bud	Flowering Date	Plant Height at Flowering Date	Last Useable Day of Flower	Number of Useable Days of Flower	Number of Leaves	Average Leaf Length	Length of Flower Cup	Diameter of Flower Cup	Final Height of Flower	Top Dry Weight
0 days at 18-20°C vs 0 days at 7°C (9/27 planting date)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Storage Temperature	.01	.01	.01	.01	.01	.01	.01	.01	NS	NS	.01	NS
DATE	.01	.01	.01	.01	.01	.01	NS	.01	.01	NS	.01	.01
Temperature * DATE	.01	.01	.01	.01	.01	.01	NS	NS	NS	NS	NS	NS
DATE: Linear	.01	.01	.01	NS	.01	.01	NS	.01	.01	.01	.01	.01
Quadratic	.01	.01	NS	.01	NS	NS	NS	NS	NS	NS	.01	.01
Cubic	.05	NS	NS	.01	NS	NS	NS	.05	NS	NS	.05	.01
18-20°C												
DATE: Linear	.01	.01	.01	NS	.01	.01	NS	.01	.01	.05	.01	.01
Quadratic	NS	.01	NS	.01	NS	NS	NS	NS	.01	NS	.01	.01
Cubic	NS	NS	NS	.01	NS	NS	NS	NS	NS	NS	NS	NS
7°C												
DATE: Linear	.01	NS	.01	NS	NS	.01	.05	NS	.01	.05	NS	.05
Quadratic	.01	.01	.05	NS	.05	NS	NS	NS	NS	NS	NS	NS
Cubic	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	.05	.01

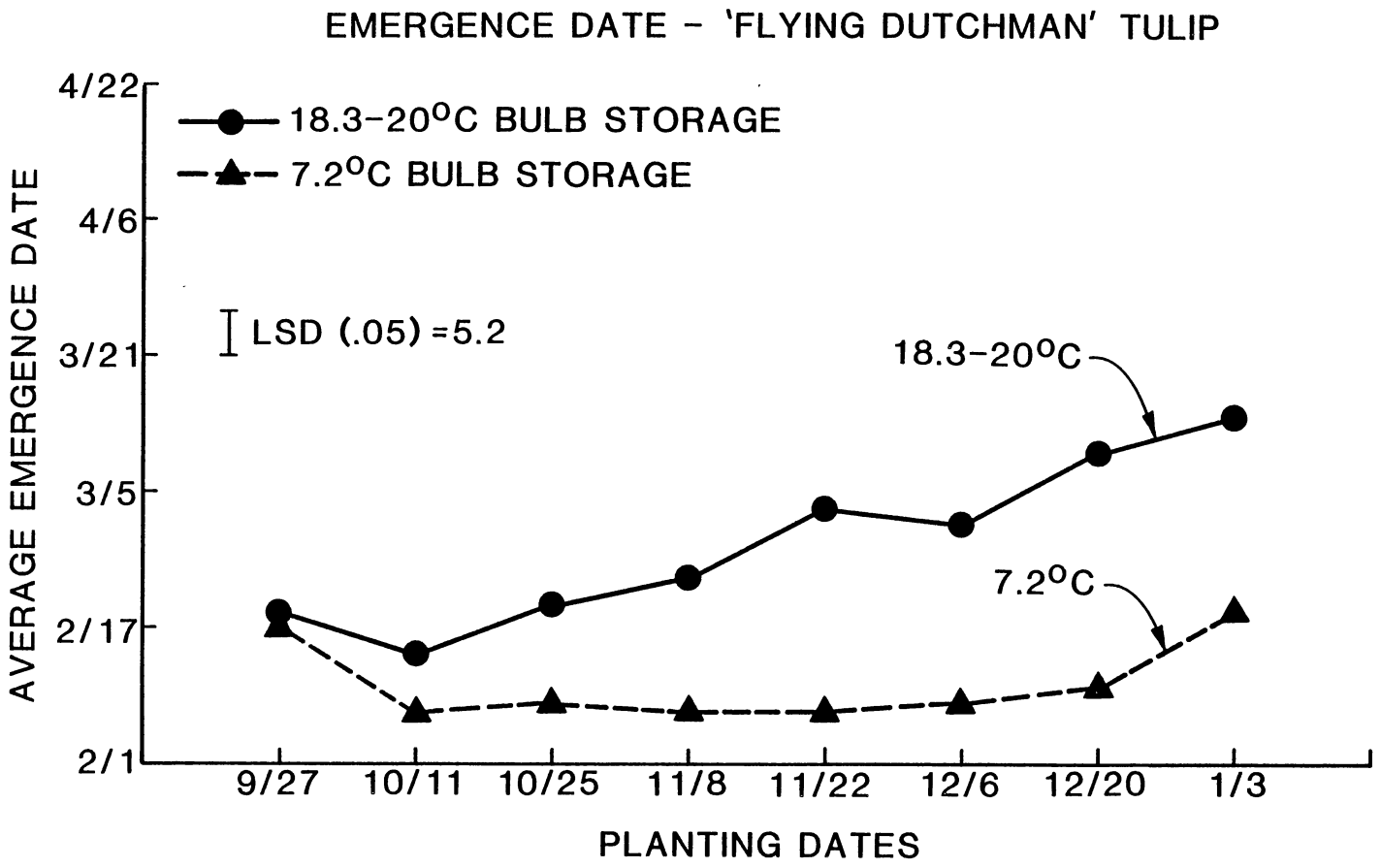

Figure 2. Emergence Date of 'Flying Dutchman' Tulip

> differentiation which must be satisfied before normal extension growth can occur at the higher temperatures associated with spring (p. 401).

It is probable that storing tulip bulbs at 7°C for 4 through 14 weeks satisfied this low-temperature requirement. Bulbs stored at 18-20°C needed more time after planting to satisfy these requirements.

The first visible bud (Figure 3) appeared significantly earlier when bulbs were stored at 7°C for 4 through 14 weeks. The first visible bud of bulbs stored at 18-20°C appeared later, the later the bulbs were planted.

Flowering date of a tulip was recorded when the flower was in full color and the petals were beginning to separate. After 4 through 14 weeks of storage bulbs stored at 7°C flowered significantly earlier than bulbs stored at 18-20°C (Table I, Figure 4). Bulbs stored at 7°C flowered, on the average, 21 days earlier. Bulbs planted October 11 after 2 weeks of storage at 18-20°C had a flowering range extending from March 25 through April 11. Bulbs stored at 7°C and planted October 11 flowered from March 15 through April 11. Bulbs stored at 18-20°C planted December 20 (12 weeks of storage) flowered April 25 through May 5. Bulbs stored at 7°C and planted December 20 flowered March 15 through April 11. Again, the later the warm-stored bulbs were planted, the later they flowered. This agrees with testing done on tulips in 1954-55 by Gill, Beijer, Stuart and Gould (15).

The useable life of the tulip flower was significantly

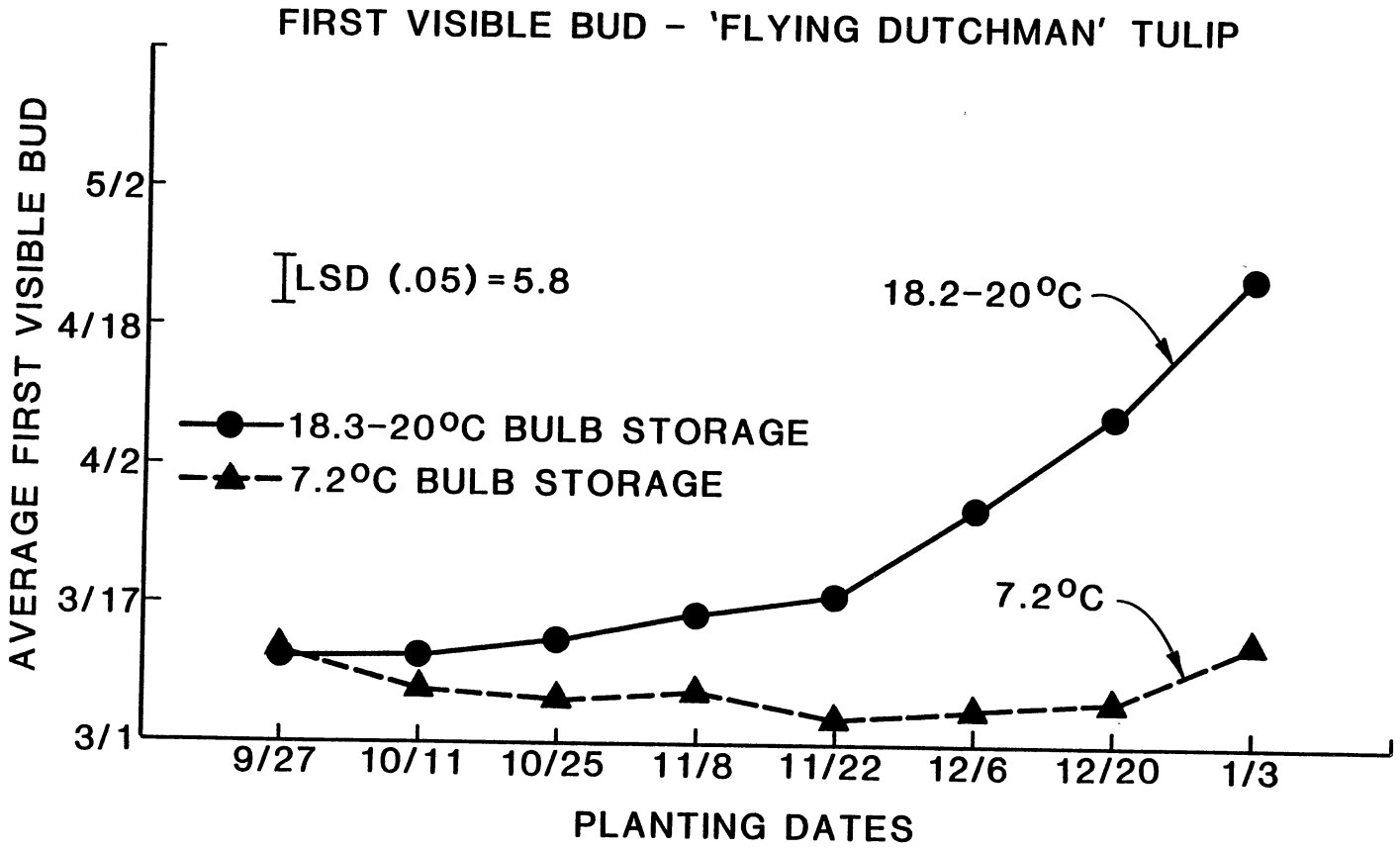

Figure 3. First Visible Bud of Tulip

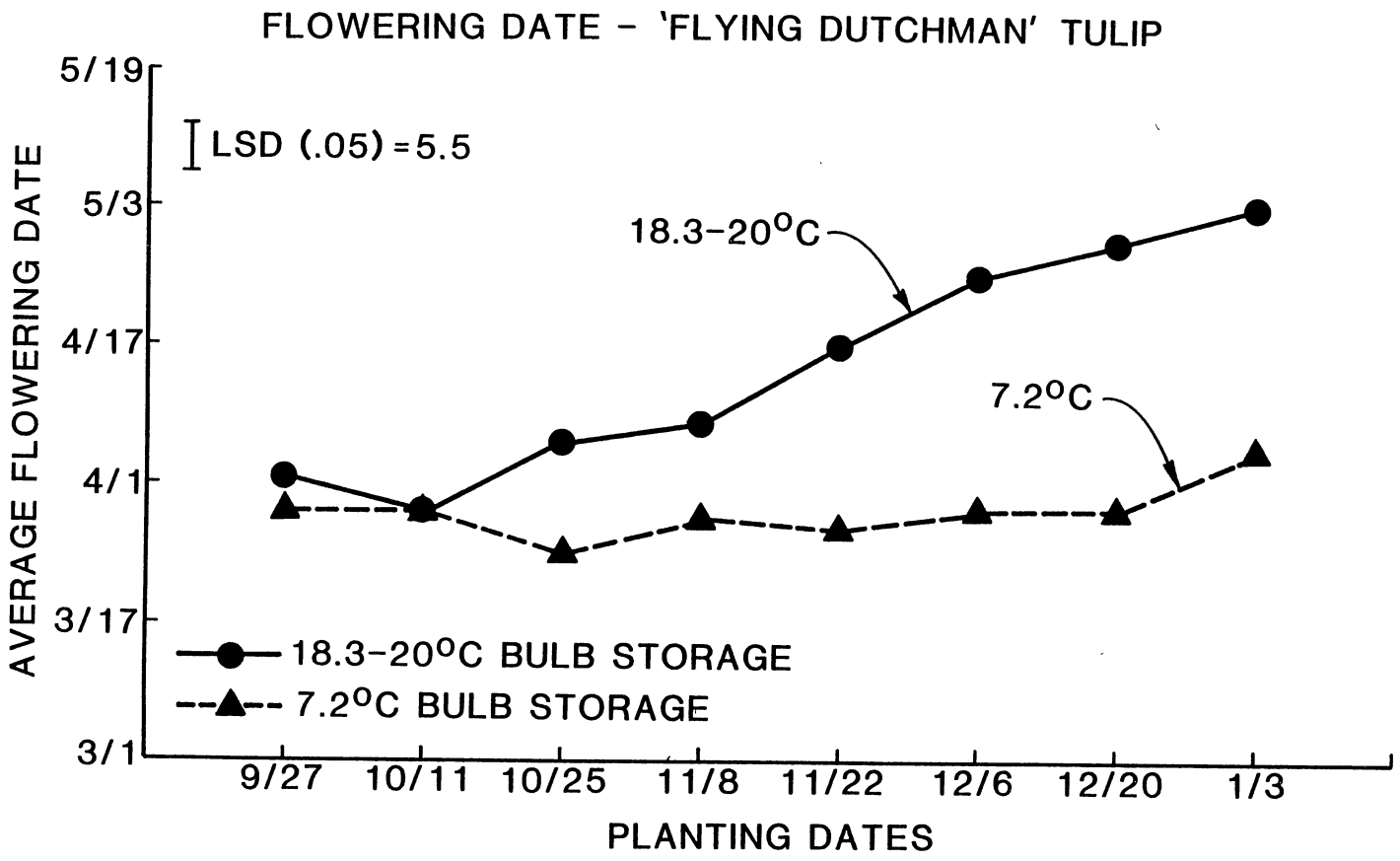

Figure 4. Flowering Date of 'Flying Dutchman' Tulip

longer (an average of 9 days) when the bulbs were stored for 4, and 8 through 14 weeks at 7°C (Table I, Figure 5). The flowers of bulbs stored at 18-20°C had an increasingly shorter life span the longer the bulbs were stored at this temperature before planting. It is also interesting to note that a flower of a bulb stored at 7°C for 14 weeks and planted January 3 had a useable life of about 18 days. A bulb stored at 18-20°C for 14 weeks and planted January 3 produced a flower with a useable life of only 6 days. One reason for the longer useable life of the flower may be related to the air temperatures during flowering (Figure 6). Bulbs stored cool and planted January 3 flowered on the average April 4 when temperatures were around 7°C (Figures 6 and 4). Bulbs stored warm and planted January 3 flowered May 3 and temperatures reached almost 32°C (Figures 6 and 4). Thus, the cool air temperatures may have acted as a natural cooler for the earlier flowering bulbs, extending their useable life.

Final plant height recorded just before petal fall, was significantly taller for bulbs stored 12 through 14 weeks at 7°C (Table I, Figure 7). There was no significant difference in final plant height between storage temperatures from 0 through 11 weeks of storage. Flower height was also recorded when flowering dates were recorded.

Rees (25) discusses the work of Aung and DeHertogh (1967, 1968). Their work was on "the presence of gibberellin-like substances in tulip, and the relation

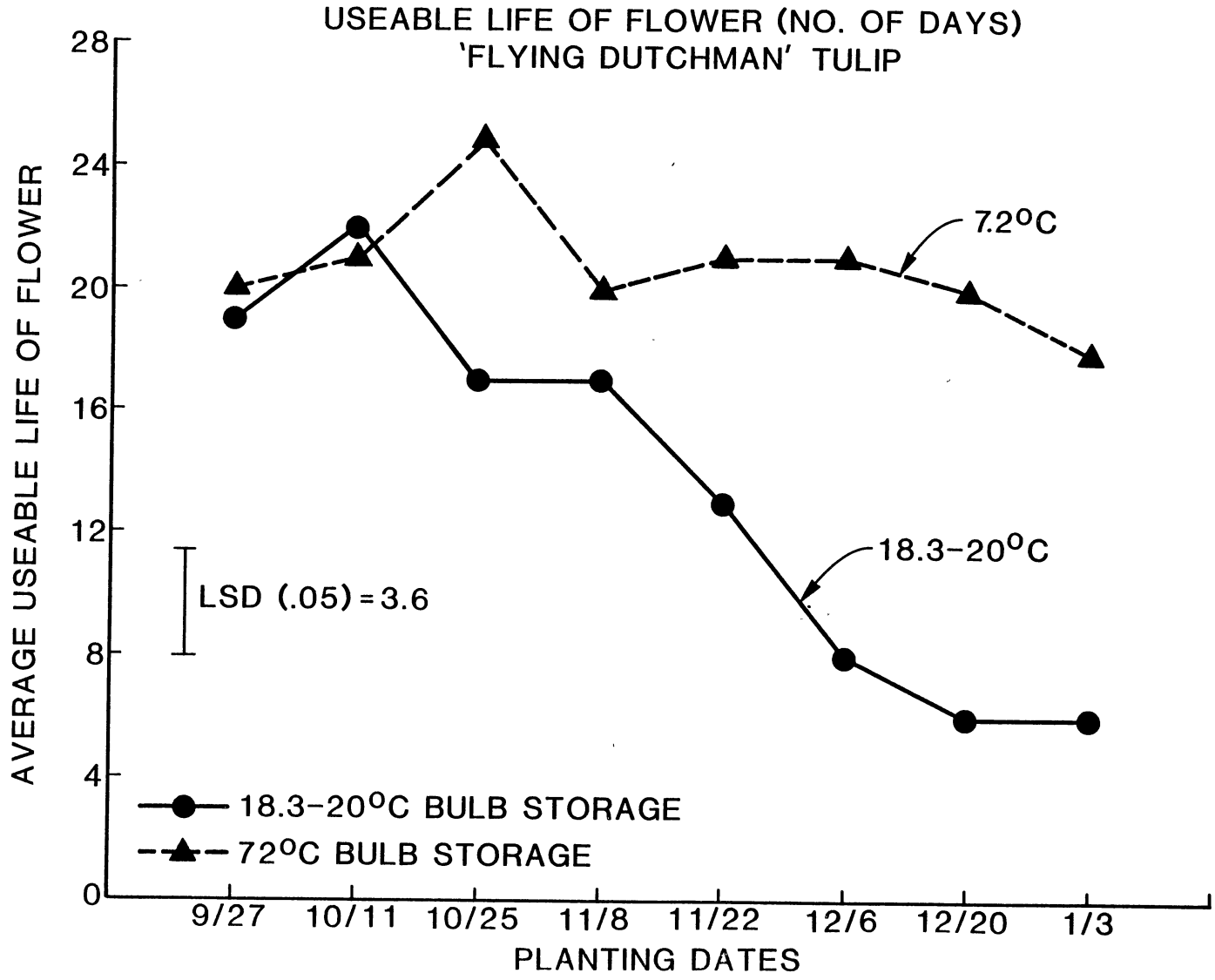

Figure 5. Useable Life of Flower (No. of Days) of 'Flying Dutchman' Tulip

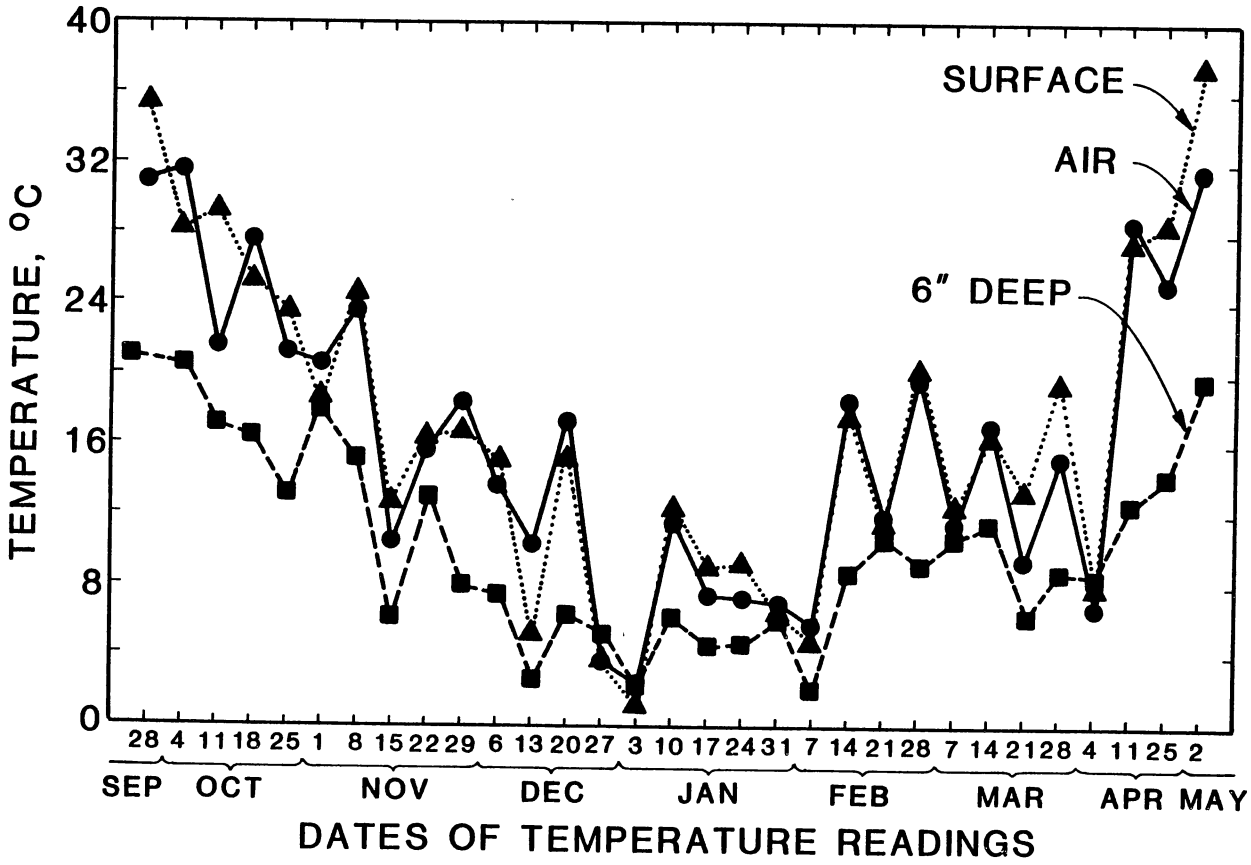

Figure 6. Temperatures of Soil Surface, Air, and at Planting Depth of Soil

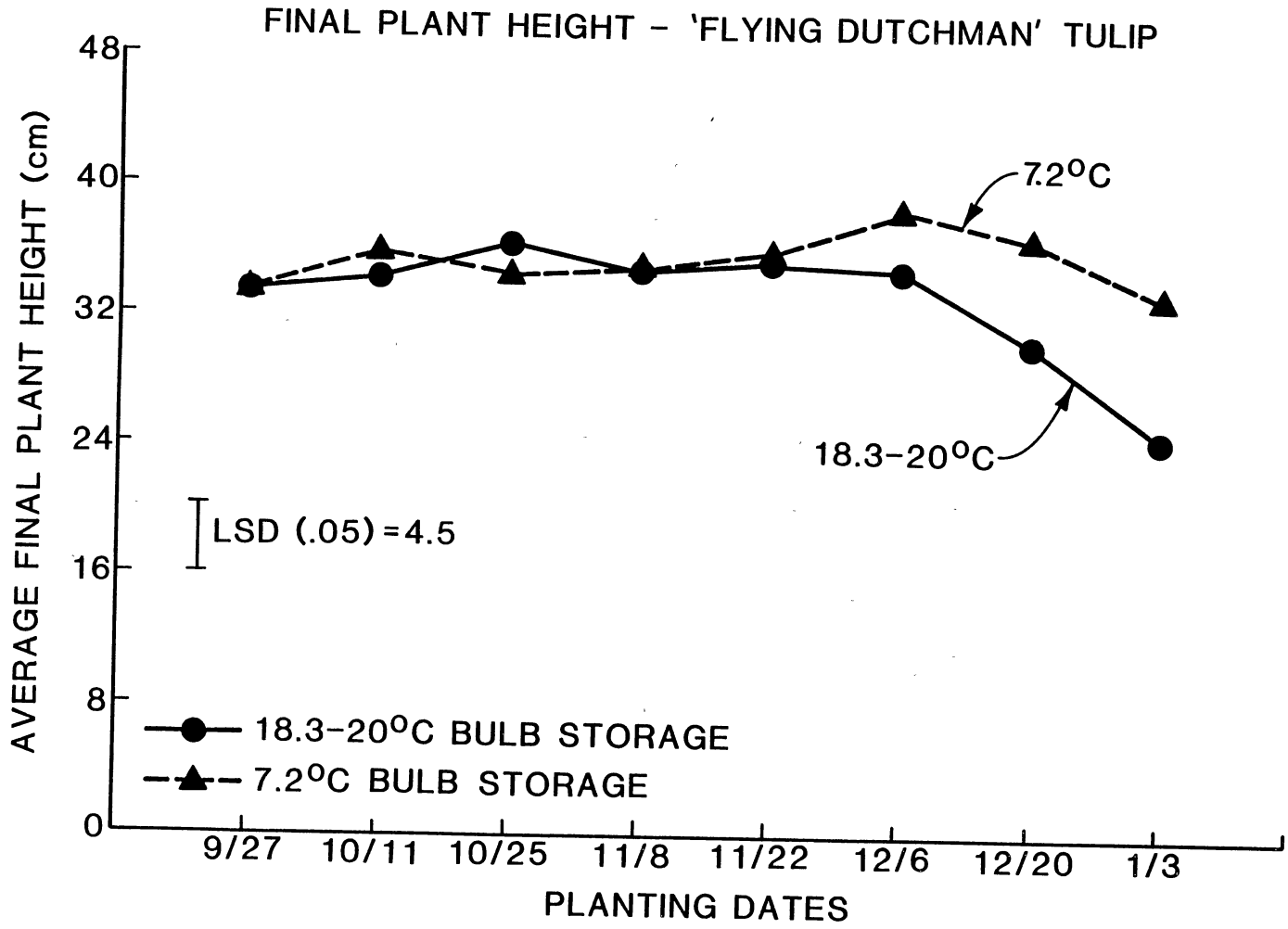

Figure 7. Final Plant Height of 'Flying Dutchman' Tulip

between gibberellin content in free and bound forms with low-temperature treatment" (p. 220). The concentration of free forms were found to increase in cool storage at 9°C up to 13 weeks, whereas the bound forms decreased slightly after 4 through 5 weeks at 9°C and gradually rose in concentration after 8 and 13 weeks. Rees (25) also states findings of his work.

> In tulip abscissic acid has been identified in bulbs before the start of precooling (Aung and Rees, unpublished), and the interaction between abscissic acid and gibberellin could be the key to plant behavior in relation to low-temperature treatment (p. 223).

Table II shows the increased plant height from its measurement on the flowering date to its measurement on the last useable day. There was an average increase of 12 cm in the height of the flower from time of flowering until the last useable day. For example, a bulb stored warm and planted September 27 had a height of 21 cm when it first flowered. On its last useable day this same flower had a final height of 34 cm, a 13 cm increase in height. Gill et al. (15) found "It is evident that bulbs planted without precooling consistently produced much shorter stems than the precooled ones" (p. 455) and they also gave some reasons for these results.

> In the field stem lengths increased markedly between opening and maturing of flowers. Bulbs planted 10 cm (4 in) deep had longer stems than those planted 20 cm (8 in) deep. Shading consistently increased stem length (p. 455).

Thus, inconsistency in planting depth as well as shading from the greenhouses could have an effect on stem length.

TABLE II

PLANT HEIGHT AT FULL BLOOM, FINAL PLANT HEIGHT, FLOWER DIMENSIONS, NUMBER OF LEAVES AND LENGTH OF LEAVES OF TULIPS

Planting Dates	Temperatures	Initial Plant Height (cm)	Final Plant Height (cm)	Cup Height (cm)	Cup Diameter (cm)	Number of Leaves	Length of Leaves (cm)
September 27	No Storage	21.0	34.0	6	5	6	19.0
		20.0	33.5	6	5	5	19.0
October 11	18-20°C	20.0	34.0	6	5	8	23.5
	7°C	22.0	36.0	6	6	8	24.0
October 25	18-20°C	20.5	36.0	6	6	8	23.0
	7°C	22.0	34.0	6	5	6**	23.0
November 8	18-20°C	18.0	35.0	6	5	8	22.0
	7°C	24.0*	35.0	6	5	7	22.0
November 22	18-20°C	21.0	35.0	6	5	8	22.0
	7°C	25.5**	36.0	6	5	7	23.0
December 6	18-20°C	28.0	35.0	6	5	9	22.0
	7°C	25.0	38.0	6	5	6*	23.0
December 20	18-20°C	26.0	30.0	6	5	8	21.0
	7°C	25.0	37.0	6	5	7	25.0**
January 3	18-20°C	15.0	24.0	5	5	8	18.0
	7°C	24.0*	33.0	6	5	5*	22.0*

(Significant difference between storage temperatures at a given planting date.)
* Significant to the 1% level.
** Significant to the 5% level.

They (15) also observed "Later blooming, fewer flowers, and shorter stems were obtained if the bulbs were planted without cool storage" (p. 453). Our data also agreed with this.

The average above-ground dry weight was not significantly different due to different bulb storage temperatures (Table III). However, those bulbs planted October 11 through December 20 had a significantly higher average dry weight than those planted September 27 and January 3. For this reason, it appears that when all factors including dry weight were considered, October through December planting dates were the most optimum.

Remaining data are shown in Table II. There were significantly more leaves on bulbs stored 4, 10 and 14 weeks at 18-20°C. For example after 14 weeks (planted January 3) of warm storage the bulb had an average of 8 leaves, but bulbs stored cool only had an average of 5 leaves (Table II). An observation made when taking this data was that a warm stored bulb might have more leaves, but these were often more narrow and shorter than leaves of bulbs stored cool. A bulb stored at 18-20°C for 14 weeks (planted January 3) had 8 leaves and an average leaf height of 18 cm, while a bulb stored at 7°C for 14 weeks (planted January 3) had 5 leaves and an average leaf height of 22 cm. The average vegetative height (to the top of the leaves) was significantly taller for those stored at 7°C after 12 and 14 weeks of storage. Bulbs at 2, 8, and 10 weeks of storage at

TABLE III

PLANT DRY WEIGHT - TULIP

Bulb Storage Temperature	Avg. Dry Wt. per Plant at Maturity - Tulip Planting Date 9/27	10/11	10/25	11/8	11/22	12/6	12/20	1/3
18.3-20°C	3.52_{ab}	4.95_{cd}	5.20_{d}	5.30_{d}	4.64_{cd}	5.02_{cd}	3.98_{bc}	2.63_{a}
7.2°C	3.33_{a}	5.12_{b}	4.23_{ab}	4.49_{b}	4.54_{b}	4.62_{b}	4.75_{b}	3.31_{a}
Significance	NS	NS	NS	NS	NS	NS	NS	NS

Means followed by the same letter within rows are not significant at the 5% level by Duncan's multiple range test. Within columns (NS) - non-significant, (*) - significant at the 5% level.

7°C also had taller leaves than bulbs stored at 18-20°C even though the difference was not significant. The cup length and diameter were not statistically different from September 27 through January 3 regardless of planting dates or storage temperatures.

These results may be due to the long periods of warm storage which could have caused bulb deterioration, thus producing shorter stems, and leaves, and a lower above ground dry weight.

Hyacinths

Hyacinths responded similarly to tulips. After 4 through 14 weeks at 7°C storage, these bulbs emerged and flowered significantly earlier than bulbs stored at 18-20°C (Table IV, Figures 8 and 9). Bulbs planted October 11 after 2 weeks of warm storage flowered March 22 through April 18. Bulbs stored cool for 2 weeks and planted October 11 flowered March 15 through April 11. In comparison after 10 weeks of storage (planted December 6) at 18-20°C bulbs flowered April 11 through May 2 and bulbs stored at 7°C for 10 weeks (planted December 6) flowered March 14 through April 7. The later the warm-stored (18-20°C) bulbs were planted, the later they emerged and flowered. Emergence for 7°C-stored bulbs averaged 22 days earlier and flowering averaged 23 days earlier than 18-20°C-stored bulbs. Tulips also showed this earliness in flowering and emergence. The first visible bud (Figure 10) emerged significantly earlier

TABLE IV

SIGNIFICANCE OF MAIN EFFECTS AND INTERACTIONS - HYACINTHS

Source of Variation	Emergence Date	Date of 1st Visible Bud	Flowering Date	Plant Height at Flowering Date	Last Useable Day of Flower	Number of Useable Days of Flower	Number of Leaves	Average Leaf Length	Length of Flower Spike	Diameter of Flower Spike	Final Height of Flower	Top Dry Weight
0 days at 18-20°C vs 0 days at 7°C (9/27 planting Date)	NS	NS	NS	NS	NS	NS	NS	NS	.01	NS	NS	NS
Storage Temperature	.01	.01	.01	.01	.01	.01	NS	.01	.01	NS	.01	.05
DATE	.01	.NS	.01	.05	.01	.01	NS	.01	.01	NS	.05	.01
Temperature * DATE	.01	NS	.01	.01	.01	.01	.01	NS	.01	NS	NS	NS
DATE: linear	.01	.01	.01	NS	.01	.01	NS	.01	.01	.05	.01	.01
Quadratic	.01	NS	.01	NS	.01	.01	NS	.01	.01	NS	.01	NS
Cubic	NS	NS	NS	.01	NS	NS	NS	NS	NS	NS	NS	NS
18-20°C												
DATE: linear	.01	.01	.01	.01	.01	.01	NS	.01	.01	NS	NS	.01
Quadratic	.01	NS	.01	.01	.01	.05	NS	NS	.01	.05	NS	NS
Cubic	NS	NS	NS	.01	NS	NS	.05	NS	.01	NS	NS	NS
7°C												
DATE: linear	NS	NS	NS	NS	NS	NS	NS	.01	NS	NS	NS	.01
Quadratic	.05	NS	.01	.01	.01	NS	NS	.05	NS	NS	.01	NS
Cubic	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

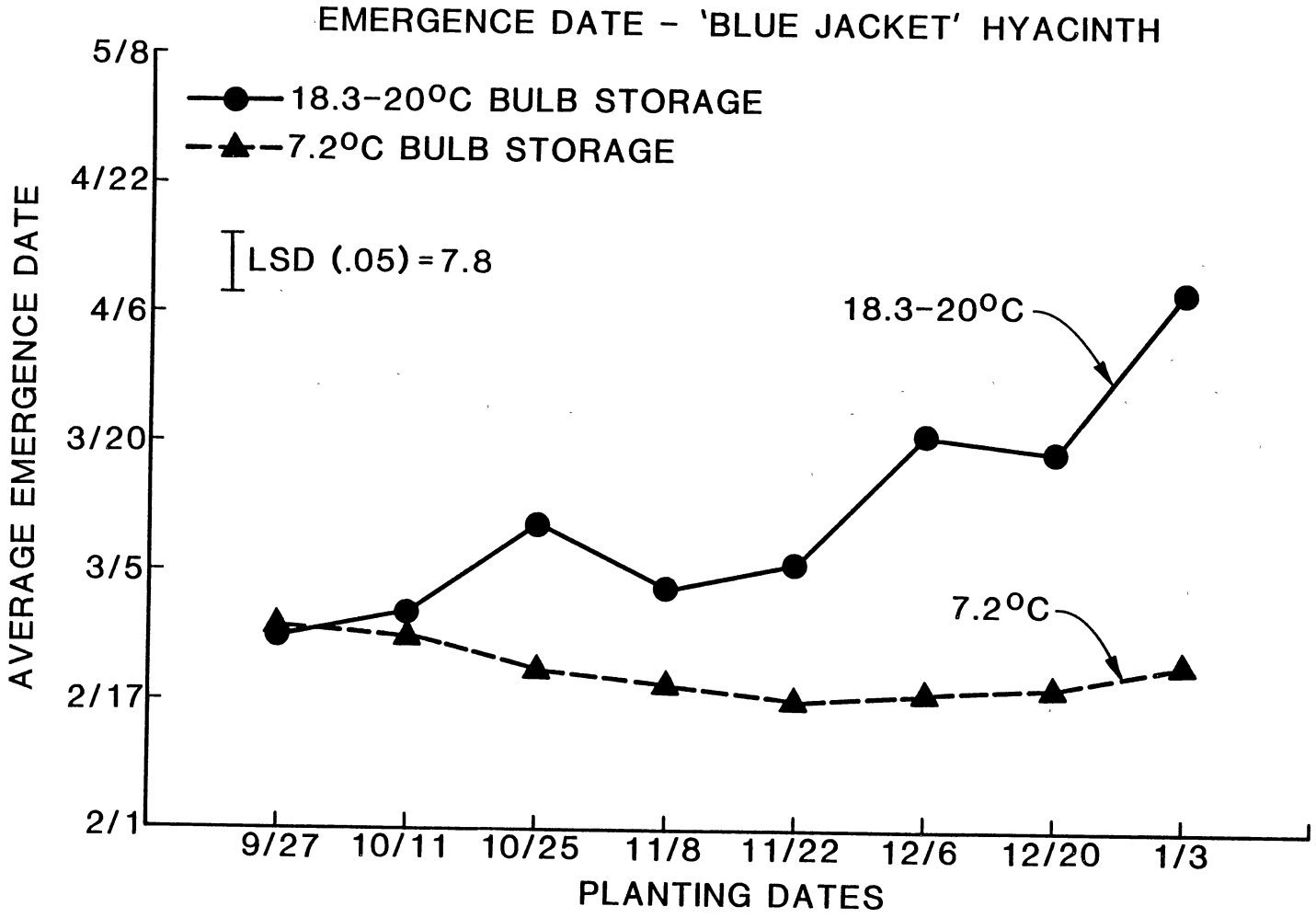

Figure 8. Emergence Date of 'Blue Jacket' Hyacinth

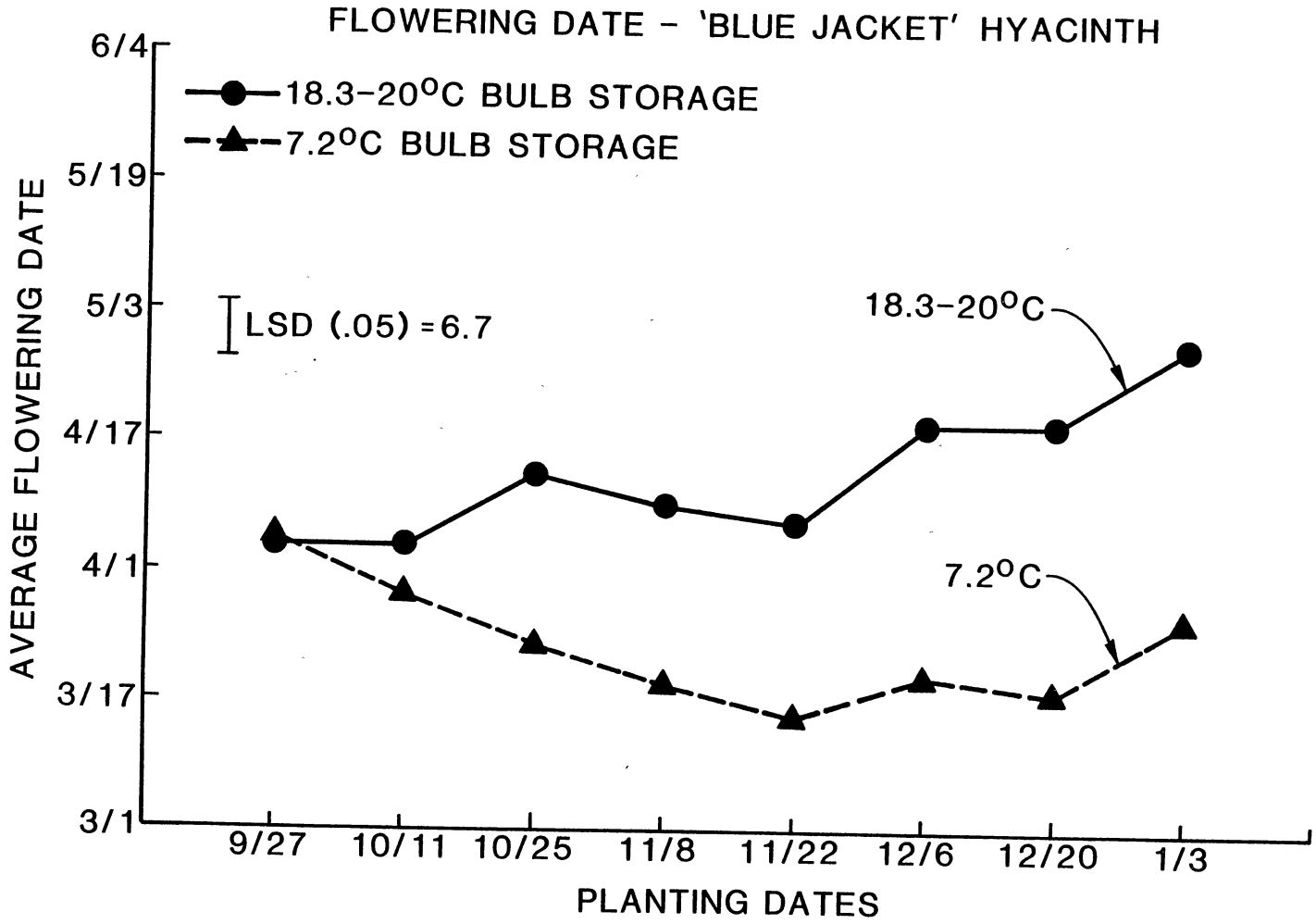

Figure 9. Flowering Date of 'Blue Jacket' Hyacinth

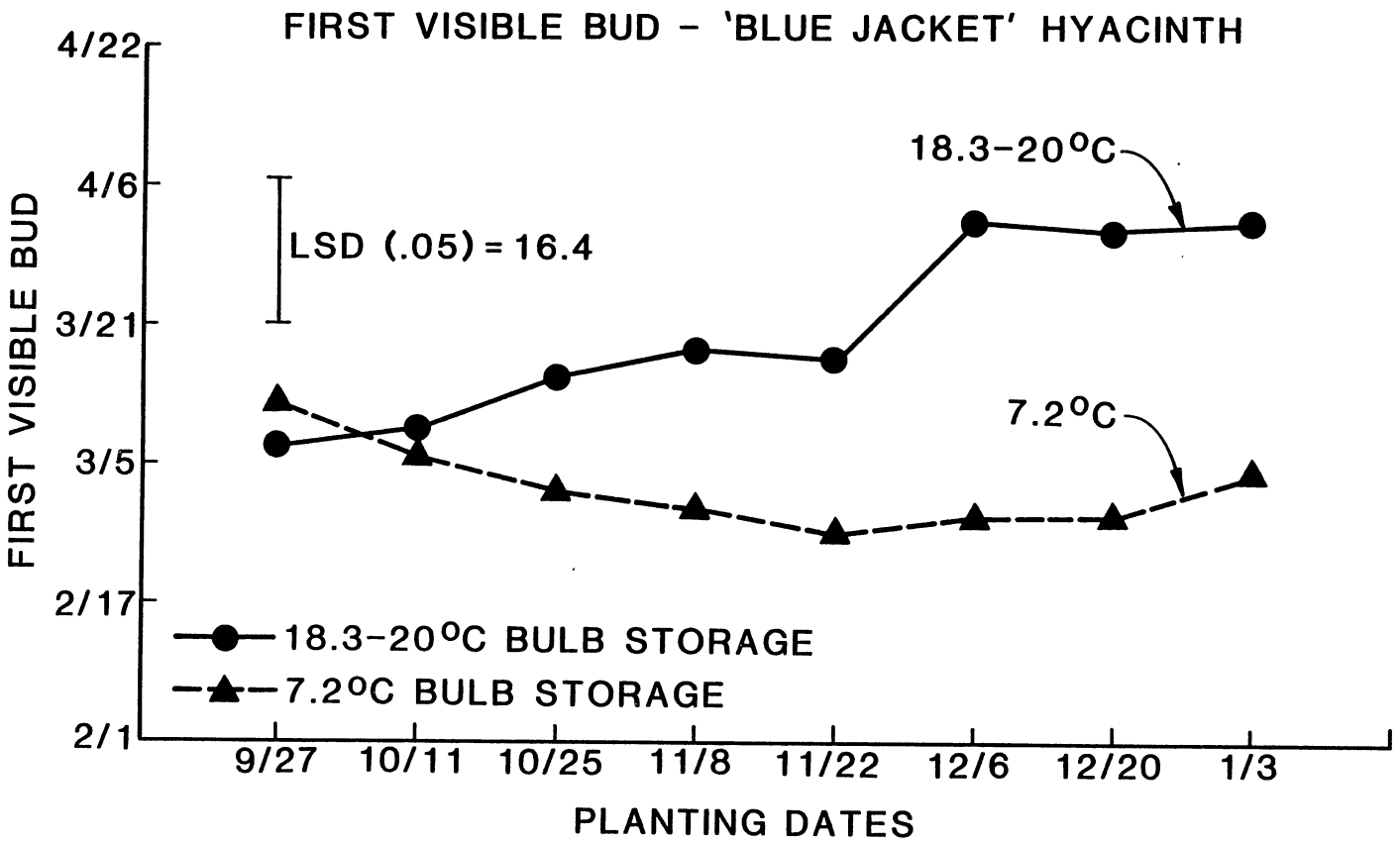

Figure 10. First Visible Bud of Hyacinth

when bulbs were stored at 7°C for 6 through 14 weeks. The first visible bud of bulbs stored at 18-20°C emerged later, the later the bulbs were planted.

Bulbs stored at 7°C had flowers with a significantly longer useable life than bulbs stored at 18-20°C (Table IV, Figure 11). These flowers lasted an average of 8 days longer. As with tulips, flowers of bulbs stored at 18-20°C had an increasingly shorter life span the longer the bulbs were stored at this temperature before planting. In Figure 10 it is important to note that bulbs stored at 7°C for 14 weeks (January 3 planting date) produced flowers with a useable life of 18 days while bulbs stored at 18-20°C for 14 weeks (January 3 planting date) produced flowers with a useable life of only 7 days. Bulbs cool-stored (7°C) and planted January 3 flowered March 27 when air temperatures were 15°C and bulbs warm-stored flowered April 29 when air temperatures were 27°C. As with tulips the cooler air temperatures may have increased the keeping quality of the flowers. Also, during the late spring there was often rain, wind and on occasion freezing temperatures. Extreme low temperatures did not appear to affect flower quality seriously, but the wind and rain did cause, in some cases, broken stems.

Final plant height (Figure 12) was significantly taller after 4 and 10 weeks of 7°C storage while, all other final heights were not significantly different. The final plant height of tulip bulbs stored at 7°C storage were not

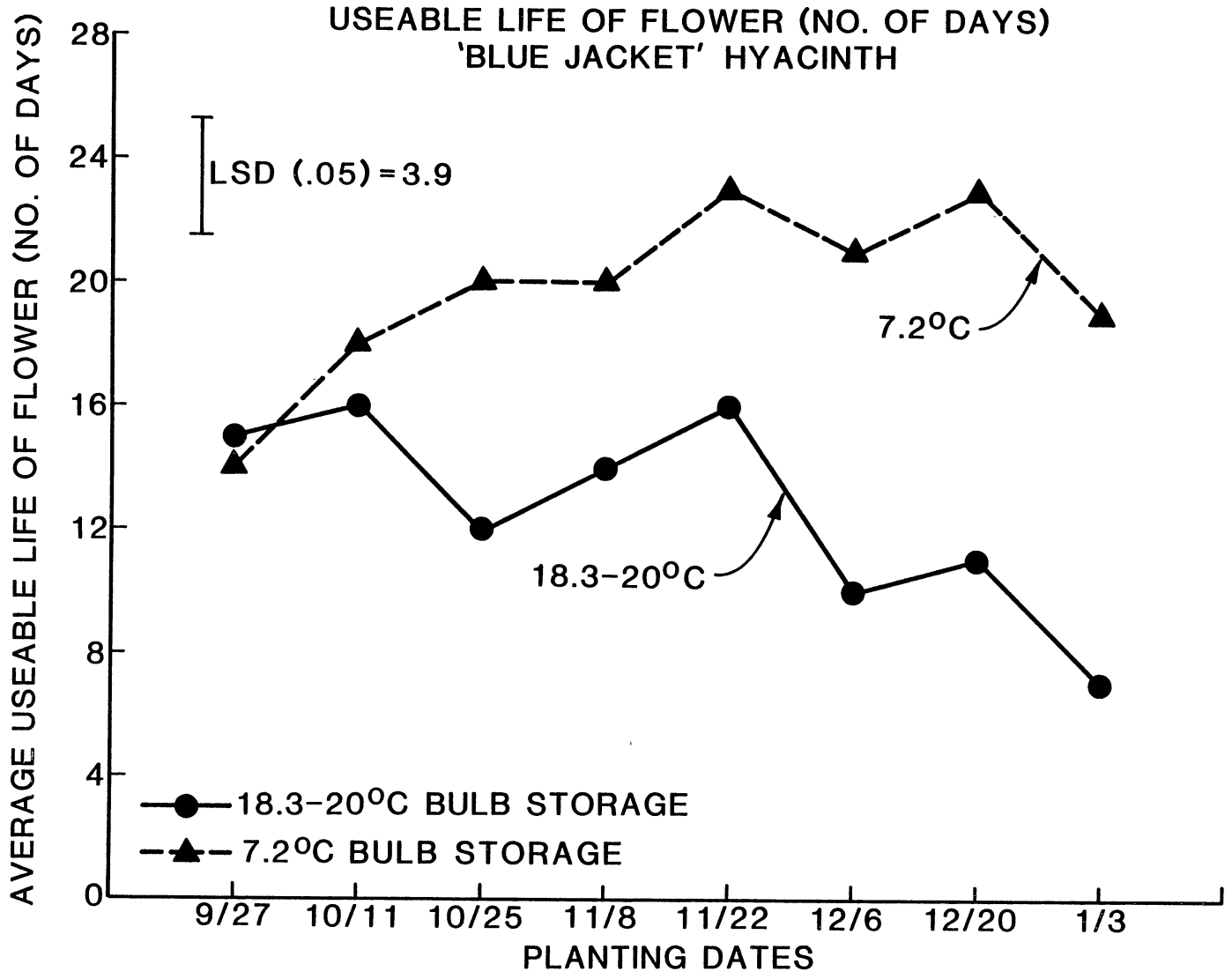

Figure 11. Useable Life of Flower (No. of Days) of 'Blue Jacket' Hyacinth

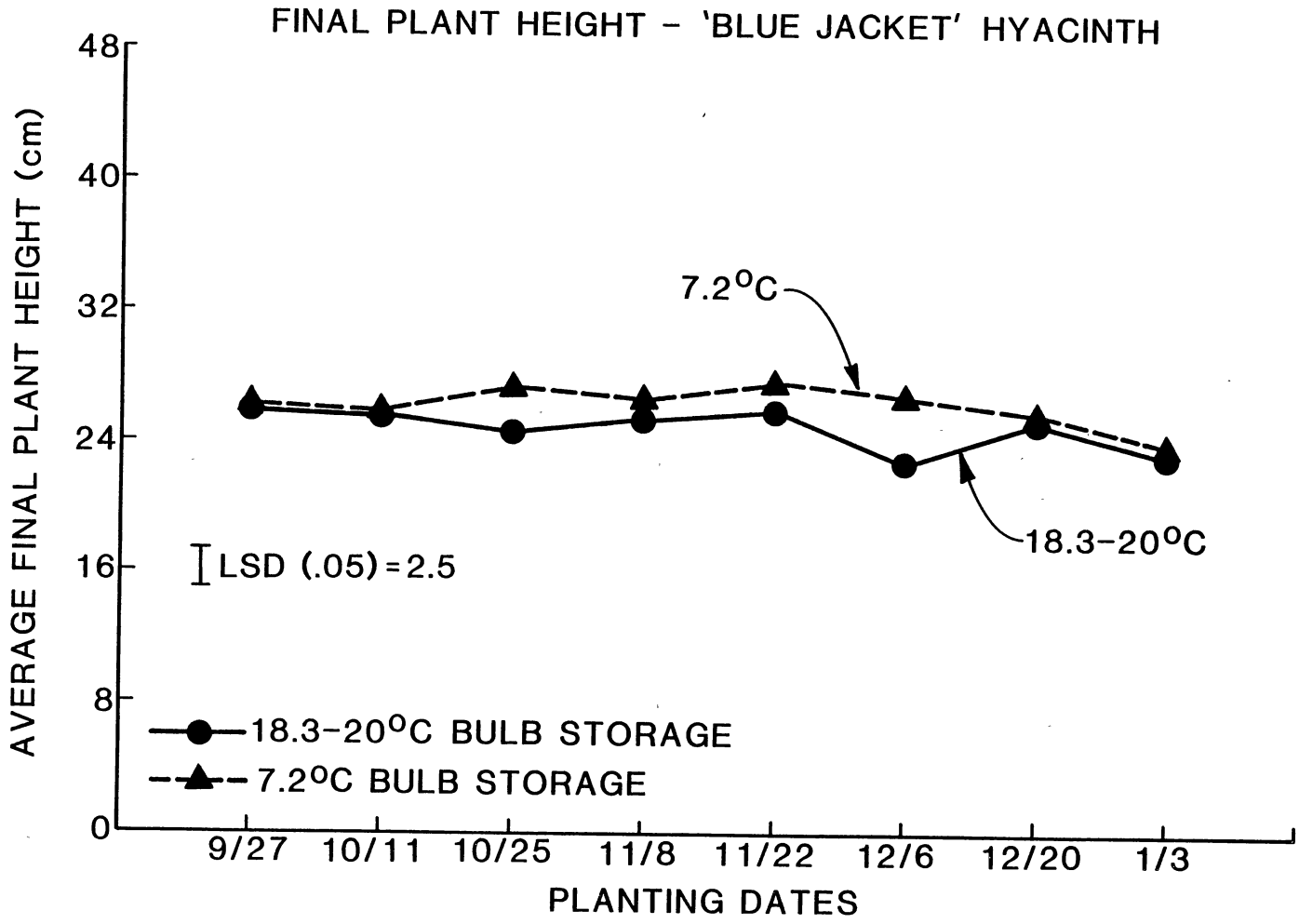

Figure 12. Final Plant Height of 'Blue Jacket' Hyacinth

significantly taller until after 12 through 14 weeks of storage. The reasons for the variation in the data are uncertain at this time.

There was no significant difference in the average above ground dry weight of plants due to storage temperatures with one exception (Table V). Bulbs stored 4 weeks (October 25 planting date) at 7°C storage had higher average plant dry weights than those stored at 18-20°C. All other plant dry weights were not significantly different due to storage temperatures. Planting date did have an effect on the dry weight. Bulbs stored at 7°C and 18-20°C had higher average plant dry weights when planted September 27 through November 22. Bulbs cool-stored also had significantly higher average dry weights when planted November 22 through January 3. However, as stated previously there was no significance due to storage temperature, even though the plant dry weights of warm-stored bulbs were not significantly different from the cool-stored bulbs, when planted November 22 through January 3.

Remaining data is presented in Table VI. From the time height of the plant was recorded at full flower until the height was recorded again on the last useable day of the flower, there was a definite increase in plant height. There was an average increase of 8 cm for bulbs stored cool, and 7 cm for bulbs stored warm. The spike diameter averaged 7 cm for all treatments and an average of 7 leaves were recorded per plant. Spike height was significantly taller

TABLE V

PLANT DRY WEIGHT - HYACINTH

Bulb Storage Temperature	Avg. Dry Wt. per Plant at Maturity - Hyacinth Planting Date							
	9/27	10/11	10/25	11/8	11/22	12/6	12/20	1/3
18.3-20°C	6.97_{bc}	8.01_{c}	5.85_{ab}	6.34_{bc}	7.13_{bc}	5.22_{ab}	5.85_{ab}	4.21_{a}
7.2°C	6.08_{ab}	6.93_{ab}	7.64_{b}	7.28_{b}	7.04_{ab}	6.76_{ab}	6.67_{ab}	5.07_{a}
Significance	NS	NS	*	NS	NS	NS	NS	NS

Means followed by the same letter within rows are not significant at 5% level by Duncan's multiple range test. Within columns (NS) - non-significant, (*) - significant at the 5% level.

TABLE VI

PLANT HEIGHT AT FULL BLOOM, FINAL PLANT HEIGHT, FLOWER DIMENSIONS, NUMBER OF LEAVES AND LENGTH OF LEAVES OF HYACINTHS

Planting Dates	Temperatures	Initial Plant Height (cm)	Final Plant Height (cm)	Spike Height (cm)	Spike Diameter (cm)	Number of Leaves	Length of Leaves (cm)
September 27	No Storage	19.0	26.0	15.0	7.0	7	38.0
		20.0	26.0	17.0*	7.5	6	34.0
October 11	18-20°C	18.0	25.0	15.5	7.5	7	36.0
	7°C	17.5	25.5	15.0	7.5	7	35.0
October 25	18-20°C	17.0	24.5	14.0	7.0	6	33.0
	7°C	18.0	27.0**	14.0	7.0	8	36.0
November 8	18-20°C	16.0	25.0	13.5	7.0	7	33.0
	7°C	20.0*	26.5	15.0	7.0	7	34.0
November 22	18-20°C	16.0	26.0	13.5	7.0	8	35.0
	7°C	20.0*	27.5	15.0	7.0	7	35.0
December 6	18-20°C	13.0	23.0	11.0	7.0	7	28.0
	7°C	20.0*	27.0*	15.0*	7.0	7	33.0*
December 20	18-20°C	13.5	25.0	11.0	7.0	7	30.0
	7°C	19.0*	25.5	15.0*	7.0	7	32.0
January 3	18-20°C	18.0	23.0	14.0	7.0	7	24.0
	7°C	18.0	24.0	14.5	7.0	7	28.0

(Significant difference between storage temperatures at a given planting date.)
* Significant at the 1% level.
** Significant at the 5% level.

for bulbs stored cool for 10 through 12 weeks and leaves were significantly taller only after 10 weeks of cool storage. Leaves of cool-stored bulbs were generally taller although not significantly. Storage temperature did not appear to seriously affect the size of the flower spike or the height and number of leaves.

Daffodils

Results for daffodils followed the same trends as for tulip and hyacinth. Bulbs stored at 7°C for 4 through 8 weeks and 14 weeks emerged significantly earlier than those stored at 18-20°C (Table VII, Figure 13). Cool-stored bulbs emerged, on average, 27 days earlier than warm-stored bulbs. The later warm-stored bulbs were planted the later they emerged.

Rees (25) states in his book The Growth of Bulbs that daffodils like tulips as mentioned earlier in this paper, have a low-temperature requirement that must be satisfied before elongation can occur in the spring. Our results indicated that cool-stored bulbs satisfied this one low-temperature requirement after 4 through 8 weeks and 14 weeks of 7°C storage. Bulbs stored warm required more time to complete this low-temperature requirement.

The first visible bud (Figure 14) emerged significantly earlier when bulbs were stored at 7°C for 6 through 14 weeks. The first visible bud of bulbs stored at 18-20°C emerged later, the later the bulbs were planted.

TABLE VII

SIGNIFICANCE OF MAIN EFFECTS AND INTERACTIONS - DAFFODILS

Source of Variation	Emergence Date	Date of 1st Visible Bud	Flowering Date	Plant Height of Flowering Date	Last Useable Day of Flower	Number of Useable Days of Flower	Number of Leaves	Average Leaf Length	Length of Flower Cup	Diameter of Perianth	Total Flowers	Top Dry Weight
0 days at 18-20°C vs 0 days at 7°C (9/27 planting date)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Storage Temperature	.01	.01	.01	.01	.01	.01	.01	NS	NS	.01	NS	.01
DATE	.01	.01	.01	.01	.01	.05	NS	.01	NS	.01	NS	.01
Temperature * DATE	NS	.01	.01	NS	.01	.05	NS	NS	.05	.05	NS	NS
DATE: Linear	.01	.01	.01	.01	.01	.01	NS	.01	NS	.01	NS	.01
Quadratic	NS	.01	.01	NS	.01	NS	NS	NS	NS	NS	.05	NS
Cubic	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
18-20°C DATE: Linear	.01	.01	.01	.01	.01	.01	NS	.01	NS	NS	NS	.01
Quadratic	NS	.01	.05	NS	NS	NS	NS	NS	NS	NS	NS	NS
Cubic	NS	NS	NS	NS	.05	NS	NS	NS	NS	NS	NS	NS
7°C DATE: Linear	.01	NS	.01	NS	NS	NS	.01	.01	.01	.01	NS	.01
Quadratic	NS	.01	.01	NS	.01	NS	NS	NS	NS	NS	NS	NS
Cubic	NS	NS	NS	.05	.01	NS	NS	NS	NS	NS	NS	NS

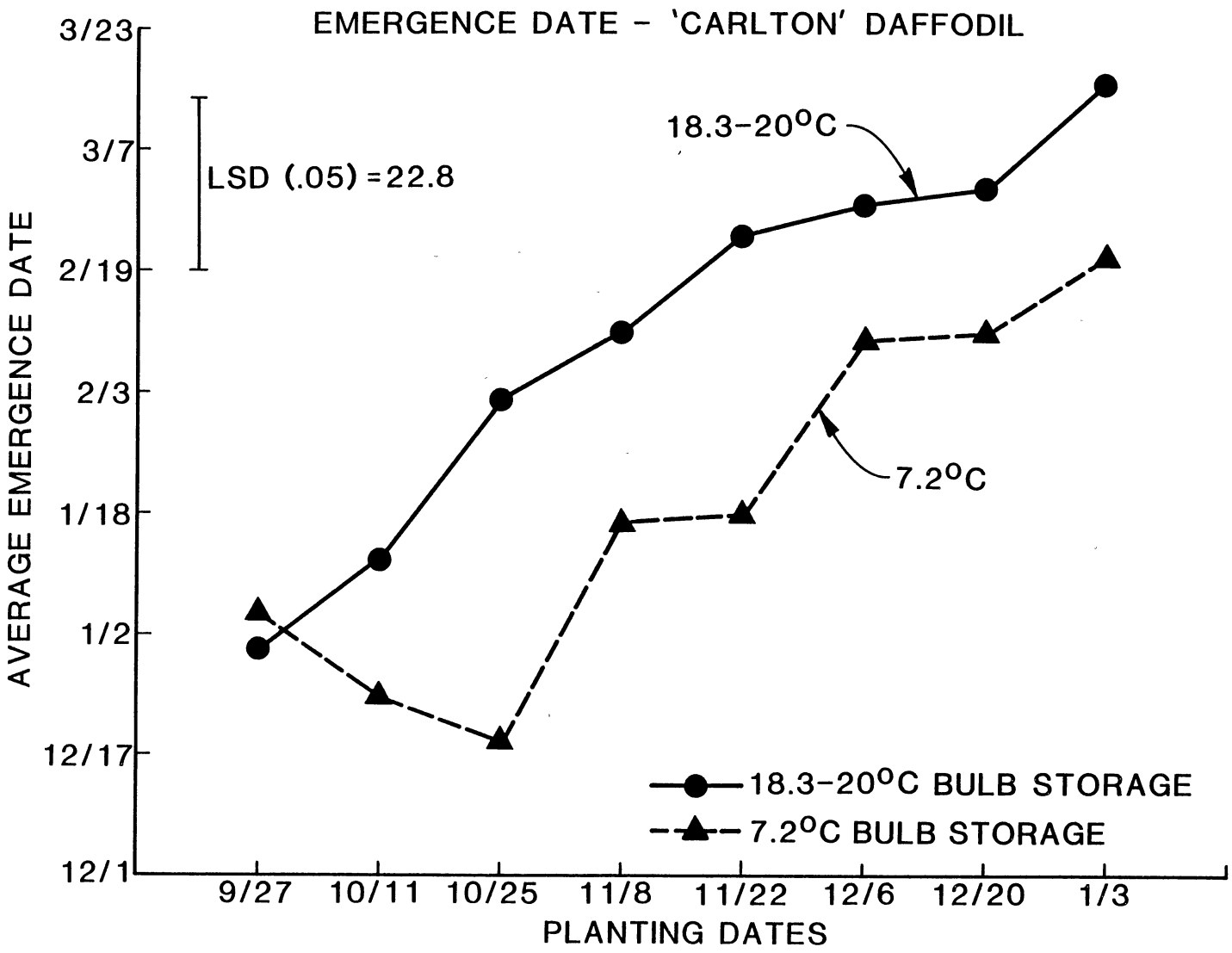

Figure 13. Emergence Date of 'Carlton' Daffodil

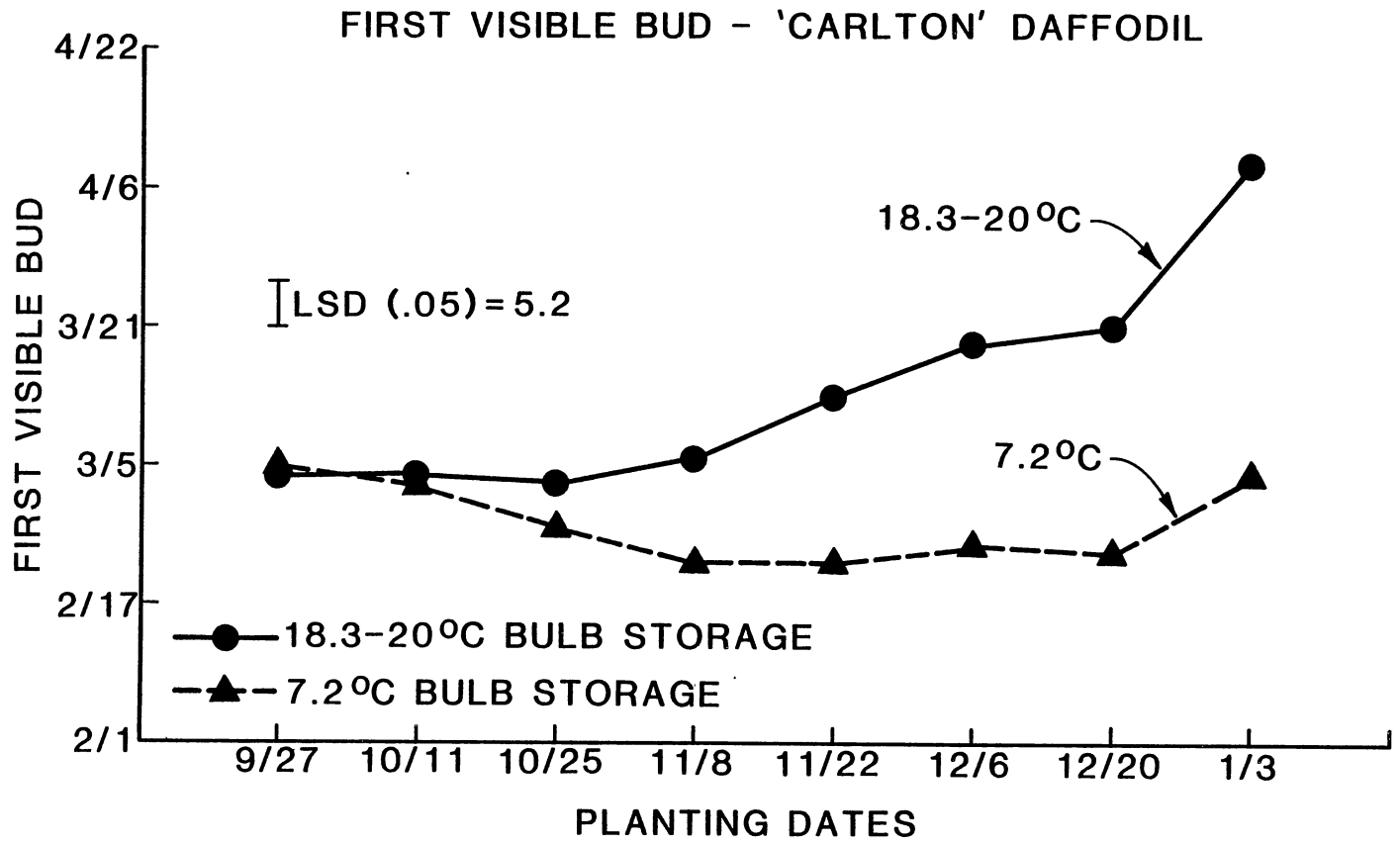

Figure 14. First Visible Bud of Daffodil

Bulbs stored at 7°C for 4 through 14 weeks flowered significantly earlier than bulbs stored at 18-20°C (Table VII, Figure 15). Cool-stored bulbs flowered on the average, 27 days earlier than warm-stored bulbs. As observed in the emergence data, the later the warm-stored bulbs were planted the later they flowered. Rees and Wallis (24,25) found that after storing narcissus bulbs at 9°C for 0, 2, 4 and 6 weeks before planting, that earlier flowering of up to 22 days occurred for 'Golden Harvest' and 28 days for 'Magnificance' and flower quality was not seriously affected. Our findings also agree with Rees and Wallis, although, we used 'Carlton' daffodils instead of 'Golden Harvest' or 'Magnificence' daffodils.

Useable life of the first flower was significantly longer after 4 through 10 and 14 weeks of storage at 7°C (Table VII, Figure 16). Flower life was approximately 5 days longer. Bulbs stored at 18-20°C had an increasingly shorter life span the later they were planted. This decrease in the useable life of the flower was not as dramatic as seen in hyacinth and tulip bulbs stored at 18-20°C. For example after 10 weeks (December 6 planting date) of warm storage daffodil flowers remained useable for 12 days (Figure 15) and tulip flowers for only 8 days (Figure 4). Daffodil bulbs planted December 6 flowered April 15 (Figure 15) when temperatures were 13°C (Figure 6). Hyacinth bulbs flowered April 19 (Figure 9) and tulips flowered April 25 (Figure 4) when temperatures were 13°C

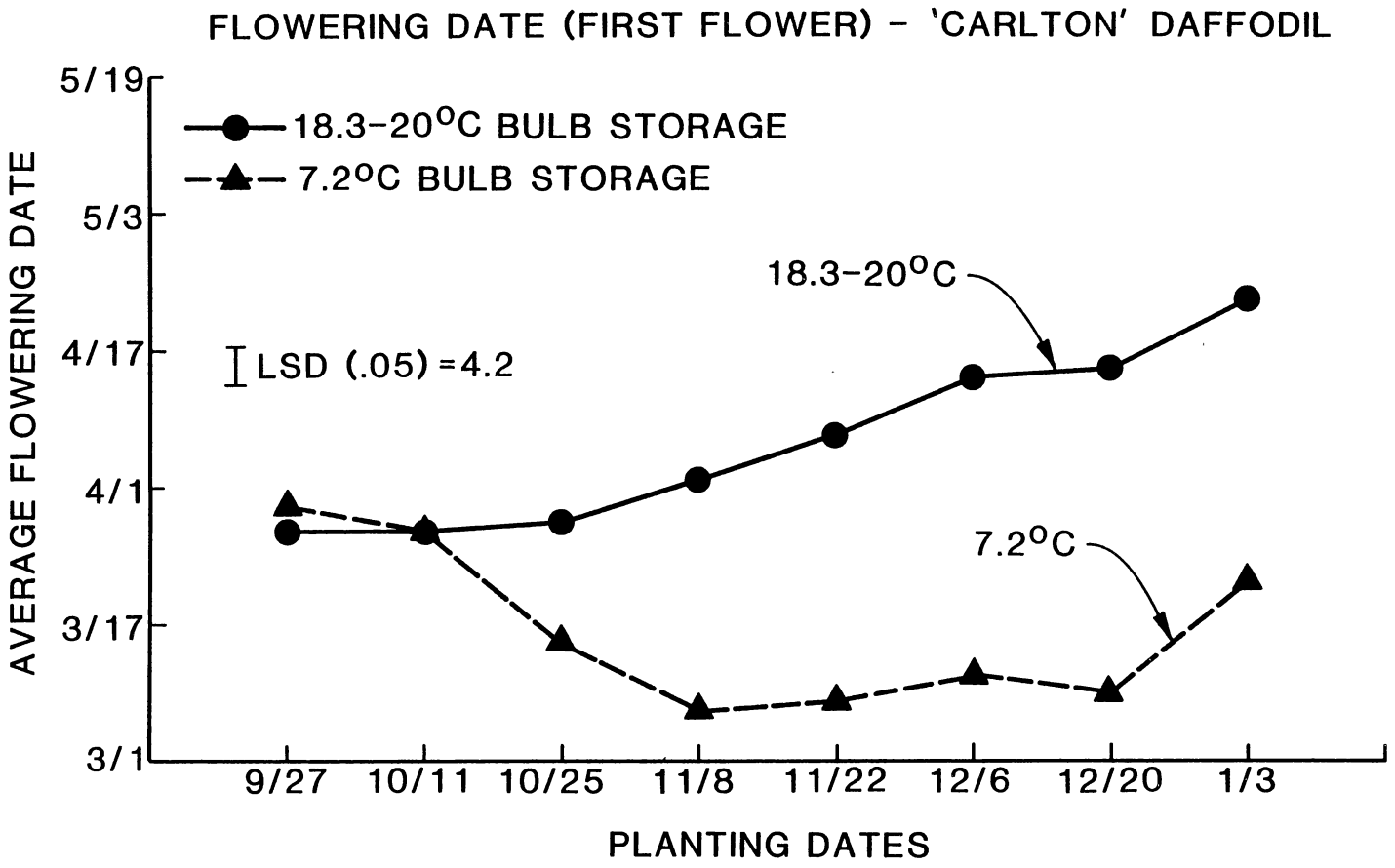

Figure 15. Flowering Date (First Flower) of 'Carlton' Daffodil

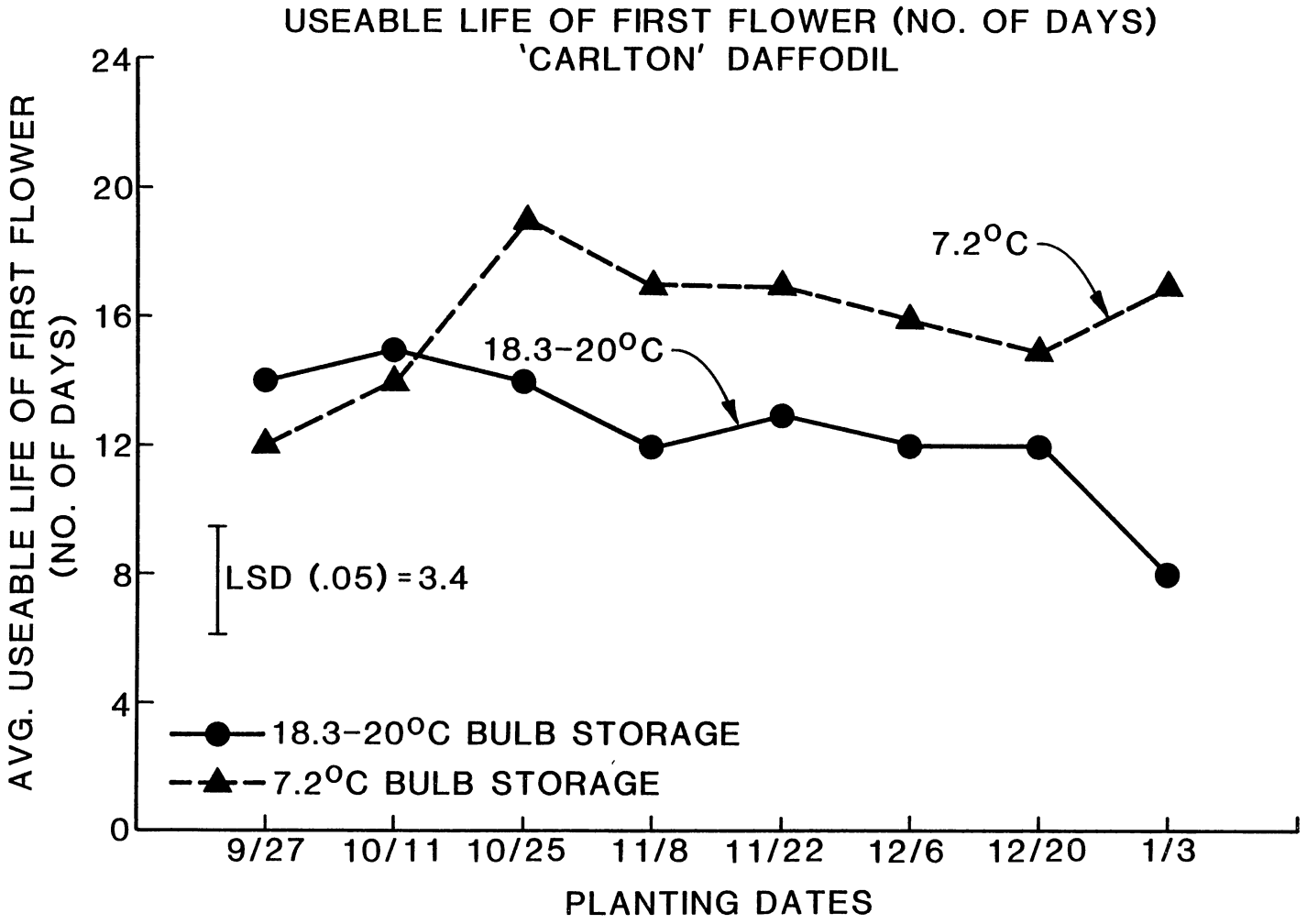

Figure 16. Useable Life of First Flower (No. of Days) of 'Carlton' Daffodil

and 14°C (Figure 6). Air temperature here did not appear to contribute to the useable life of the flower.

During flowering in the spring there were occasional freezing temperatures, rain and wind. As with hyacinth and tulip, flower quality of the daffodil was not noticeably affected by low temperatures. The wind and rain did cause petal loss on tulips, and broken stems on both hyacinths and tulips. However, daffodils withstood all three environmental conditions well.

It is interesting to also note that 7°C-stored bulbs when planted January 3, after 14 weeks of storage produced flowers with a life span of 17 days. Flowers of bulbs stored at 18-20°C for 14 weeks and planted January 3 had a life span of only 8 days (Figure 16). These results may also be related to the air temperature at that time. The 7°C-stored bulbs planted January 3 flowered March 22 when temperatures were 9°C and the 18-20°C stored bulbs planted January 3 flowered April 23 when temperatures were 13°C (Figure 6). The cooler temperatures probably aided in lenghtening the useable life of the flower.

The highest average above ground dry weights (Table VIII) for bulbs stored at 18-20°C and 7°C were those planted October 11 through November 8. The plant dry weights of bulbs planted September 27, November 22 through December 6 and January 3, were not significantly different. This may indicate daffodils cannot be stored longer than 2 through 6 weeks or adverse effects result. There was no significant

TABLE VIII

PLANT DRY WEIGHT - DAFFODILS

Avg. Dry Wt. per Plant at Maturity - Daffodils								
Bulb Storage Temperature	Planting Date							
	9/27	10/11	10/25	11/8	11/22	12/6	12/20	1/3
18.3-20°C	11.08_{ab}	14.31_{cd}	15.46_{d}	14.27_{cd}	11.76_{bc}	10.28_{ab}	11.92_{bc}	8.26_{a}
7.2°C	11.04_{bcd}	13.67_{de}	14.08_{e}	12.40_{cde}	10.47_{bc}	9.52_{bc}	9.12_{ab}	6.42_{a}
Significance	NS	NS	NS	NS	NS	NS	*	NS

Means followed by the same letter within rows are not significant at the 5% level by Duncan's multiple range test. Within columns (NS) - non-significant, (*) - significant at the 5% level.

difference in dry weight due to different bulb storage temperatures with one exception. Bulbs planted after 12 weeks (December 20 planting date) of storage at 18-20°C had a higher average dry weight than those stored at 7°C. However, when all factors were considered including dry weight, October 11 through November 8 planting dates were the most optimum.

Remaining data are shown in Table IX. No final plant height was recorded on daffodil, but plant height at the time of full bloom was recorded. Bulbs stored 4 weeks (planted October 11) and 6 weeks (planted November 8) at 7°C were significantly shorter. All other treatments showed no significant differences due to storage temperature. Trumpet length averaged 3 cm for all treatments while perianth varied some between 9 and 10 cm. Bulbs stored at 18-20°C for 6 and 10 through 14 weeks had significantly more leaves (an average of 6 more leaves) than bulbs stored at 7°C. The average heights of the leaves, however, were not significantly different. In the discussion of tulip leaves, bulbs with more leaves did not always indicate a better plant. This observation was also true for daffodils. Plant dry weight was significantly higher after 2 through 6 weeks of storage but not after 10 and 14 weeks.

TABLE IX

PLANT HEIGHT AT FULL BLOOM, FLOWER DIMENSIONS, NUMBER OF LEAVES AND AVERAGE HEIGHT OF LEAVES OF DAFFODILS

Planting Dates	Temperatures	Initial Plant Height (cm)	Trumpet Length (cm)	Perianth Diameter (cm)	Number of Leaves	Average Height of Leaves (cm)
September 27	No Storage	31.0	3.0	10.0	19	43.0
		35.0	3.0	10.0	21	45.0
October 11	18-20°C	32.5	3.0	10.0	21	53.0
	7°C	31.0	3.0	10.0	22	51.0
October 25	18-20°C	34.0	3.0	10.0	25	52.0
	7°C	27.0*	3.0	10.0	23	52.0
November 8	18-20°C	33.0	3.0	10.0	27	50.0
	7°C	26.0*	3.0	9.5	21*	46.0
November 22	18-20°C	30.0	3.0	10.0	24	44.0
	7°C	26.0	3.0	10.0	20	45.5
December 6	18-20°C	27.0	3.0	10.0	24	42.0
	7°C	25.5	3.0	9.5	19**	44.0
December 20	18-20°C	27.5	3.0	10.0	26	43.0
	7°C	28.0	3.0	9.0	19*	42.0
January 3	18-20°C	25.0	3.0	10.0	24	34.0
	7°C	25.0	3.0	9.0	16*	34.0

(Significant difference between storage temperatures at a given planting date.)
* Significant at the 1% level.
** Significant at the 5% level.

CHAPTER V

CONCLUSIONS

Tulip, daffodil and hyacinth bulbs stored at 7°C emerged and flowered earlier than bulbs stored at 18-20°C. In addition, for all 3 species, bulbs stored at 7°C had a longer useable flower life than those bulbs stored at 18-20°C. Probably this was due partially to cooler temperatures which were prevalent during earlier flowering of the cool-stored bulbs. Even though freezing temperatures occurred during earlier flowering, there was little or no flower damage. As seen in the graphs, bulbs stored 18-20°C and planted after October 25 had a later flowering date the later the bulbs were planted. When all factors are considered, including total plant dry weight, any planting date from October 11 to December 6 or December 20 would be satisfactory for tulips and hyacinths. October 11 to November 8 planting dates would be considered satisfactory for daffodils.

Although further study is needed, precooling bulbs in Oklahoma may have value in achieving earlier flowering and thus extending the total flowering period.

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