THE EFFECT OF FOUR STORAGE TREATMENTS ON SEED YIELD AND YIELD COMPONENTS OR THREE ONION INBREDS

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PETER STANDISH HESSE

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ABSTRACT

THE EFFECT OF FOUR STORAGE TREATMENTS ON SEED YIELD AND YIELD COMPONENTS OF THREE ONION INBREDS

By

Peter Standish Hesse

Three M.S.U. onion inbreds, 661-20, 826, and 2399, were given the following storage treatments: 2°C 24 weeks, 2°C 12 weeks-10°C 12 weeks, 10°C 12 weeks-2°C 12 weeks, and 10°C 24 weeks.

The 2°C 24 week treatment delayed the emergence of inbreds 2399 and 826 while 10°C for 24 weeks delayed inbred 661-20.

Flowering was delayed for approximately 5 days by storage at 2°C for 24 weeks, while storage at 10°C for 24 weeks or at 10°C for the second 12 weeks resulted in the earliest flowering. If 2°C was given during the second 12 weeks, flowering was delayed for approximately 2.5 days. The flowering of inbred 661-20 was little affected by the storage treatments.

The 10°C 24 week treatment resulted in the shortest primary seedstalks and the 10°C 12 week-2°C 12 week treatment the tallest. Inbred 661-20 produced the shortest primary seedstalks after the 2°C 24 week treatment, while inbreds 2399 and 826 produced the tallest.

The 10°C 24 week and 10°C 12 week-2°C week treatments resulted in the most leaves per plant.

Inbred 661-20 produced 1 umbel per bulb regardless of the storage treatment, but storage at 2°C for 24 weeks or at 2°C for the

second 12 weeks resulted in a significantly greater number of florets per umbel (therefore per bulb).

Storage of inbred 826 at 2°C for 24 weeks resulted in 1.48 umbels and the fewest florets per bulb. Storage at 2°C for the first 12 weeks resulted in approximately the same number of umbels (1.68), but a significantly greater number of florets per bulb. If 2°C was given for the second 12 weeks, inbred 826 again produced approximately the same number of umbels (1.38), but only an intermediate number of florets per bulb. The 10°C 24 week treatment resulted in 2.49 umbels per bulb. This increase of 1 umbel per bulb did not increase the total florets per bulb, but resulted in significantly fewer florets per umbel.

Inbred 2399 produced 4.25 umbels after the 10°C 24 week treatment, while storage at 2°C for 24 weeks resulted in 2.69 umbels. The combination treatments resulted in 3.29 umbels per bulb. Although for 2399 the number of umbels per bulb varied dramatically, the total florets per bulb did not. The florets were simply distributed over the number of umbels.

For inbreds 2399 and 826, the higher number of umbels did not produce the highest number of florets or seed yield per bulb. For all three inbreds storage at 10°C for the first 12 weeks followed by 2°C for 12 weeks resulted in a high number of florets per umbel and the highest seed set and seed yield per umbel.

The fewest seeds per floret occurred after the 10°C 24 week treatment.

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To my grandmother

Mrs. Myles Standish

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I. INTRODUCTION

Onion seed production has become a highly specialized operation, especially since the advent of hybrids. Seed yields have fluctuated and many years have been very low, largely due to pollination problems.

One factor that has long been known to affect flowering and seed yield is the storage temperature of the mother bulbs (Atkin and Davis, 1954; Jones, 1927; Jones and Emsweller, 1939; Woyke and Manczek, 1965). Extremely high or low temperatures may inhibit or delay flower formation, while 11° to 12°C has been considered optimum (Jones and Mann, 1963). Others have found that by varying storage temperatures, especially from warm to cold, seed production was enhanced (DeMille and Vest, 1976; Van Der Meer and Van Bennekom, 1969).

The objective of this study was to increase seed yield of three M.S.U. onion inbreds by varying the storage temperatures and analyzing the yield components.

II. LITERATURE REVIEW

Temperature during the "resting" and "dormant" stages (Abdalla and Mann, 1963) of the onion bulb has a profound effect on the subsequent growth and development of the onion plant. Storage temperatures favorable for flowering and seed production are not appropriate when storing sets for bulb production. Much of the early work on storage temperature in onions was concerned with the control of bolting in sets.

The Effect of Set Storage on Bolting and Related Factors

Small sets, less than 1 gram, seldom bolt, but as the size increases so does the percentage of seeders. Jones and Boswell (1922) investigated the time of flower primordia differentiation. They concluded that at College Park, Maryland, the flower primordia were differentiated early in the spring regardless of whether the sets were planted in the fall or early the following spring.

Boswell (1923) selected in August "early maturing" and "late maturing" sets for storage at 0°, 4.4°, or 10°C. On February 28, two crates of sets were moved to 10° from the 0° and 4.4°C to simulate shipping and marketing conditions. All bulbs showing no growth or decay were planted in the field April 20. Sprouting data were taken during the storage period and growth responses were noted in the field.

Boswell found that "early maturing" sets sprouted less readily than "late maturing" sets. Losses to decay were less in the "early" than the "late" sets. Storage at 0°C resulted in the least loss. Storage at 0°C followed by 6 weeks at 10°C resulted in much more rapid growth than storage at 10°C throughout. Flower primordia differentiation was inhibited but not prevented by storage at 0°C for 8 months. Six months exposure to 0°C was less inhibitory to floral development than 8 months.

Thompson and Smith (1938) investigated the effect of temperature and size on seed stalk and bulb development. The sets were stored at -1.1°, 0°, 4.4°, 10°C, and in common storage (15.6°-20.1°C). Prior to planting, the sets were graded into three sizes: large (13/16 to 1 1/8 inch), medium (5/8 to 3/4 inch) and small (3/8 to 5/8 inch).

They noted that the smallest sets produced the fewest seedstalks. Sets stored at 4.4° and 10°C produced the highest percentage of seedstalks, while the smallest percentage was produced by sets at 15.6°-20.1°C. The high temperature, however, resulted in loss due to dehydration. The best storage temperature to maintain set quality and inhibit bolting was -1.1° to 0°C.

Sets transferred during the last month of storage from *-1.1° or 0°C* to *4.4° and 10°C* or from *15.6°-20.1°C* to *0° or 10°C* resulted in an increase in the percentage of seedstalks and a decrease in bulb yield. However, sets moved from *4.4° and 10°C* to *15.6°-20.1°C* resulted in fewer seedstalks and a higher bulb yield.

Thompson and Smith (1938) conducted microscopic studies on the apical meristems of the sets during storage to determine the time flower primordia differentiated. In late March, flower primordia

were found only in the *large* sets stored at 0°, 4.4° and 10°C. Ten days later flower primordia were found in *medium* size sets stored at 0°, and 4.4°C and 20 days later in those stored at 10°C. The *small* sets showed no elongation of the growing point at any time prior to planting in mid-May.

Thompson and Smith found the highest respiration rate was at 15.6°-20.1°C and the lowest at 0°C, but there was no correlation between respiration rate and the appearance of the flower primordia.

An intensive study of the effects of the environment on the development of the onion plant was carried out in England in the 1940's and was summarized by Heath (1945). He reported sets bolted less when stored at 0°-1.5°C for 22 weeks or for 8 weeks followed by 14 weeks at 12.5°C. However, 0°-1.5°C for the last 8 weeks of storage resulted in a sudden flush of inflorescence initiation upon return to normal temperatures (12.5°C for 6-7 weeks), and actually appeared to *increase* bolting in the field. Medium storage temperatures (10°-15°C) were the most favorable to flowering except for the accelerating effect of late cold storage.

The formation of leaf initials was also affected by storage temperature. Fewer leaf initials were produced during storage at 0°-1.5°C for 22 weeks than at 12.5°C. The two treatments, 0°-1.5°C for 22 weeks and 12.1°C for 14 weeks followed by 0°-1.5°C for 8 weeks, prevented leaf initiation during storage. The after-effect of these two treatments was a tendency for sets to produce leaf initials more rapidly on return to normal temperatures.

Heath suggested that the increase in flowering and more rapid production of leaf initials after the warm-cold-warm treatment

indicated that the onion plant was adapted to certain conditions where a cold spell in January-February is frequent.

Hartsema (1947) studied leaf and flower formation in sets of the variety Giant Zittau. The optimum storage temperature for flower formation was 13°C. The greatest number of foliage leaves was formed at storage temperatures of 17° to 20°C, but the length of the foliage leaves was greatest one season after 13°C and the other season after 23°C. Flower formation began first at 5°-13°C, later at 2°C and 17°C, and a few at 20°C, but none at higher temperatures. Hartsema found storage at a high (23° or 28°C) temperature followed by storage at 5° or 9°C resulted in abundant flower formation. However, initial low storage temperature (5°, 9° or 13°C) followed by 23° or 28°C resulted in few or no flowers

Heath and Holdsworth (1950) reported on the influence of day length and temperature on flowering of the onion plant. They noted that, under appropriate conditions, once the terminal inflorescence was initiated, more inflorescences could arise from axillary buds apparently indefinitely. Prior to the appearance of the inflorescence each bud produced at least three leaves.

They concluded there was a minimum plant size and there may be a minimum leaf number prior to floral initiation. There was a maximum temperature above which initiation could not take place. Day length did not directly affect inflorescence initiation, but bulb formation may destroy newly initiated inflorescences.

The Effect of Bulb Storage on Internal Morphology and Related Factors

Woodbury (1950) studied floral initiation in mature bulbs. He set up a factorial experiment with the following factors: 2 varieties

(Ebenezer and Sweet Spanish), 3 storage temperatures (1.7°, 10° and 20.1°C), 2 photoperiods (normal day, i.e., 10 hours, and a 15 hour day), 3 storage lengths (2, 4, and 8 months), and 3 greenhouse (growing) temperatures (10°-15.6°, 15.6°-20.1°, 20.1°-26.7°C). Following the storage treatment the bulbs were planted in the greenhouses. They were examined (by dissection) for flower primordia prior to planting and subsequently every two weeks starting January 12 and ending March 8.

A few flower primordia were found in early January for each of the treatments, and these developed rapidly in the next 8 weeks. A greater rate of initiation was noted in Sweet Spanish. Bulbs grown under the 15 hr photoperiod produced a significantly greater number of flower primordia, partly because light seemed to prevent rotting of Sweet Spanish in the warm greenhouse. Bulbs grown at 10° to 15.6°C produced the greatest number of flower primordia while almost none were initiated in bulbs growing at 20.1° to 26.7°C. Floral initiation in bulbs grown at 15.6° to 20.1°C was much less than at 10° to 15.6°C. The most effective storage temperature to induce floral initiation was 10°C, significantly fewer were initiated at 1.7°C, and 20.1°C induced the least. The length of storage had no significant effect on the development of the floral axis. Seedstalk formation took place only in the 10°-15.6°C greenhouse.

Abdalla and Mann (1963) studied the effect of storage temperature on bulb "rest." Using the cultivar Excel, they found bulbs stopped initiating leaves at the apex approximately three weeks before harvest. Bulbs resumed initiating leaves (approximately 5 weeks later) near the beginning of storage at 15°C and continued at a rate

of approximately one leaf every two weeks. In bulbs stored at 0° or 30°C, the rate of initiation was half that at 15°C.

Elongation of the inner leaves (the sprout) began after about two weeks of storage at 15°C. However, six weeks later the sprouts were not externally visible. No elongation was observed at 0° or 30°C during a 10 week examination period.

In another experiment (Abdalla and Mann, 1963), bulbs of Excel and Australian Brown were stored at 0°, 5°, 10°, 15°, 20°, 30°, and 40°C. Bulbs were removed from storage after 2, 4, 8, and 16 weeks, placed in moist sphagnum at 15°C, and checked for sprouting and rooting. They found the 5°, 10°, and 15°C treatments for any storage period resulted in the most rapid sprout emergence. Sprouts emerged the least rapidly after the 0° or 30°C treatments. The longer the bulbs were stored, the quicker they sprouted. Thus, bulb rest was not intensified by storage.

Abdalla and Mann found that root emergence always preceded sprouting. Root emergence occurred simultaneously and most rapidly after the 5°, 10° or 15°C treatments. However, after a period of growth, root lengths and weights were greater for bulbs stored at 15° than at 5° or 10°C.

Using the cultivar Excel, they studied the extent of mitosis in the shoot apex during the rest period. Mitotic figures were present from the cessation of leaf initiation (in the field) through curing and storage. However, the frequency decreased in storage, especially at 0° and 30°C. At no time was the shoot apex inactive.

In a recent study Ward (1967) stored onion bulbs for 9 months at 2°, 7.5°, 15° and 25°C and 70% R.H. He found losses due to desiccation increased with temperature, but less than 20% of the

weight loss was due to respiration. Respiration rates of bulbs transferred from 2° to 25°C were higher from February (time of transfer) onwards than bulbs stored continuously at 25°C. Conversely, bulbs transferred from 25° to 2°C respired less from February onwards than those kept at 2°C. Sprouting, measured at the final assessment in June, was highest at 7.5° and 15°C and lowest at 2°C. Total weight loss was above 45% in all storage treatments except at 2°C, where it was 12%.

The Effect of Bulb Storage on Seed Production and Related Factors

Jones (1927) studied the relationship between storage temperatures and seed yield. Using the cultivar Ebenezer, a poor seeder, he stored the mother bulbs for 4 months at 3.5°, 7.5°, 11°-12°, 16°-22°, 30°C, and in common storage. He found bulbs stored at 7.5° and 11°-12°C flowered earliest, produced the highest seed yields, and the fewest vegetative stalks.

Jones and Emsweller (1939) reported the effect of storage temperature, bulb size, spacing, and time of planting on the production of onion seed. Bulbs stored at 8° and 12°C were first to flower and ripen seed, while those stored at 30°C were the latest. Bulbs stored at 12°C produced the greatest number of umbels and the best seed yield. Both the higher and lower storage temperatures reduced seed yield.

In another experiment Jones and Emsweller used the same storage treatments but three different cultivars: a free seeding strain of Ebenezer, Yellow Globe Danvers, and Strain #15-8. The 12°C treatment resulted in the earliest flowering and 30°C the latest. For all cultivars, 12°C resulted in the most umbels, but not significantly

more than 16°-22°C or common storage. The fewest umbels resulted after the 3.6°, 8°, and 30°C treatments. The 30°C treatment resulted in the lowest seed yield for Ebenezer and Strain #15-8, while both 30°C and 8°C treatments resulted in a low yield for Yellow Globe Danvers. There was a significant interaction between cultivars and storage.

Jones and Emsweller (1939) also reported an increase in the number of umbels and seed yield per plant with an increase in bulb size (eight different sizes ranging from 15 to 90 grams). They also found an increase in seed yield per plant as the space between bulbs was increased (3, 4, 6, 8, and 12 inch spacings). Furthermore, later planting dates (1st planting December 7, December 27, January 1, January 22, January 20, February 15, March 2) of Yellow Globe Danvers delayed seed maturity and decreased seed yield.

Atkin and Davis (1954) gave the cultivar Australian Brown 4 storage treatments (0°, 10°, 20°C and common storage) and planted them at 4 times (November 16, December 15, February 12, March 24) throughout the winter. They reported the earliest planting resulted in the earliest flowering and bulbs from the 10°C storage and common storage flowered first. Earlier planting yielded more umbels, but regardless of the date of planting, 10°C and common storage gave the greatest number of umbels. Early planting with a 10°C storage treatmend yielded the highest total number of umbels.

Delayed planting resulted in fewer florets per umbel. Storage treatments appeared to have a minimum influence on the number of florets per umbel. The 0°C treatment was significantly poorer than 10°, 20°C or common storage.

Delayed planting resulted in lower seed yields. The 10°C and common storage treatments resulted in the highest seed yields, while 0°C and 20°C were lower.

Woyke and Manczek (1965) obtained the greatest number of seed stalks and seed yield from bulbs stored at 8°-12°C but reported that seed stalk number and seed yield per bulb were not closely correlated.

Van Der Meer and Van Bennekom (1968) observed differences in seed yield between 3 selections of Rijnsburger onions because one of the selections produced more seed stalks. Comparing different storage treatments, they found a constant 26°C resulted in almost no seed production. The most seed was produced when bulbs were stored at 12°C for 2-4 months followed by storage at 0°C. Storage at 0°C, preceded and followed by storage at 12°C, also gave good results, as did constant 12°C storage.

DeMille and Vest (1975, 1976) stored onion bulbs (Trapp's Downing Yellow Globe) at 7°C for 6 months, at 2°C for 3 months followed by 7°C for 3 months, and at 7°C for 3 months followed by 2°C for 3 months. They found storage at 7°C throughout resulted in the earliest flowering. The 2°-7°C treatment delayed flowering longer than the 7°-2°C treatment, but this difference was not significant. The highest seed yield resulted from the 7°-2°C treatment, while seed yield from the 7°C and 2°-7°C treatments was not different. There were no differences in the number of seedstalks. The number of seeds per plant was greatest after the 7°-2°C treatment, while there was no difference between the 7°C or 2°-7°C treatments. The number of seeds per umbel was lowest for the 7°C treatment and highest for the 7°-2°C and 2°-7°C treatments. Individual seed weight was lowest for the 7°C treatments and highest for the 7°-2°C and 2°-7°C treatments.

The seed stalks were slightly taller after the 2°-7°C and 7°-2°C treatments than after the 7°C treatment. The 2°-7°C treatment yielded the least number of leaves.

Seed Production

Mital and Srivastava (1964), using open pollinated cultivars, Pusa Red and Early Grano, investigated the relationships between the number of seed stalks, seed yield, and seed quality. The bulbs were organized into different tiller groups according to the number of seed stalks.

They found seed yield per plant increased with an increase in the number of seed stalks. For Pusa Red, seed size decreased as the number of seed stalks increased, but the seed size did not vary for Early Grano. Seed germination generally decreased with tillering increase. When the seeds were planted and subsequent bulb size compared, there appeared to be a negative correlation between the seed stalk number and the bulb size.

Prokhorev and Khomyakov (1972) determined the number of seeds in an inflorescence for onion plants flowering on July 16, 20, 25, 30, and August 5. They found the earlier flowering plants produced a greater number of high quality seeds.

III. MATERIALS AND METHODS

In 1974 and 1975, onion bulbs of three M.S.U. inbreds (661-20, 826, and 2399) were grown at the M.S.U. muck farm using standard cultural practices. The cured bulbs were sorted and graded for uniformity within each inbred line and given the following storage treatments:

1. 2°C 24 wk
2. 2°C 12 wk-10°C 12 wk
3. 10°C 12 wk-2°C 12 wk
4. 10°C 24 wk
5. 10°C 6 wk-2°C 18 wk
6. 2°C 6 wk-10°C 18 wk
7. 10°C 18 wk-2°C 6 wk
8. 2°C 18 wk-10°C 6 wk

Fifteen bulbs per treatment were used the first year and 30 bulbs the second. The bulbs for each treatment were divided into 3 subplots, i.e., there were 5 bulbs per subplot in 1975 and 10 bulbs per subplot in 1976. The experimental design was randomized complete block with 2 replications. Only treatments 1 through 4 were repeated the second year.

The following data were collected:

a) The days to sprout emergence from date of planting.

b) The days to flowering, i.e., opening of the first floret.

This umbel was tagged and called the *primary* umbel. All other umbels were called *secondary*.

c) The height of the primary seedstalk.

d) The number of umbels per bulb.

e) The number of leaves per bulb.

f) The number of florets; umbels were harvested from one subplot per treatment and the florets counted.

g) Seed yield; two subplots per treatment were used for the seed yield data in 1975 and one subplot in 1976.

h) Florets that set seed; in 1976 only, umbels were harvested (just before the seed capsules shattered) from one subplot per treatment and the florets that set seed were counted.

i) The weight per seed; 100 seeds per primary umbel and secondary umbels were counted and weighed.

j) The number of seeds per floret; 1976 only.

Seed was harvested and thrashed by hand. Light seed and chaff were floated from the good heavy seed. Seeds from the primary umbel were kept separate and seeds from the secondary umbels were bulked together for each plant.

Plot means were subjected to analysis of variance each year and (for treatments 1 through 4) for both years combined. Variance due to subplots was not included in the error variance until a preliminary F-test had been performed (Sokal and Rohlf, p. 266-267). Tukey's *hsd* procedure was used for mean separation at the 5% level (Steel and Torrie, p. 109-110).

Only the combined data of the two years are presented and discussed in the text. All AOV tables may be found in the Appendix.

IV. RESULTS AND DISCUSSION

Days to Sprout Emergence (Table 1)

Storage at 2°C for 24 weeks delayed emergence by approximately 2 days. Inbred 2399 emerged first, followed by inbred 826, 2 days later, and inbred 661-20, 12 days later.

Storage at 2°C for 24 weeks delayed the emergence of inbreds 826 and 2399. However, inbred 661-20 responded in an opposite manner and 10°C for 24 weeks delayed emergence. The combination treatments had little effect on inbreds 2399 or 826, but 10°C for the second 12 weeks of storage delayed the emergence of inbred 661-20 as much as 10°C for the whole 24 weeks.

This difference in response suggests the inbreds may require special handling to achieve optimum results in a breeding program.

Days to Flowering (Table 2)

Storage at 10°C for 24 weeks or 10°C for the second 12 weeks resulted in the earliest flowering. The treatment, 2°C for 24 weeks, delayed flowering by approximately 5 days, while storage at 2°C for the second 12 weeks delayed flowering by approximately 2.5 days. These trends agree with earlier reports (Atkin and Davis, 1954; DeMille and Vest, 1975; Jones, 1927; Jones and Emsweller, 1939). Both inbreds 2399 and 826 flowered at the same time and 6 days before inbred 661-20.

Table 1. Mean number of days to sprout emergence of 3 onion inbred lines following 4 storage treatments

Storage treatment	Inbred[x] 2399	826	661-20	Treatment means
2°C 24 wk	26.8f b	26.4f b	32.0g a	28.4 B
2°C 12 wk- 10°C 12 wk	19.9f a	24.5g ab	35.5h bc	26.6 A
10°C 12 wk- 2°C 12 wk	22.7f a	25.2f ab	32.8g ab	26.9 A
10°C 24 wk	20.5f a	23.1f a	36.2g c	26.6 A
Inbred means	22.5F	24.8G	34.1H	

[x]Means in columns followed by the same letter (a to b) and means in rows followed by the same letter (f to h) are not significantly different at the 5% level.

Table 2. Mean number of days to flowering of 3 onion inbred lines following 4 storage treatments

Storage treatment	Inbred[x] 2399	826	661-20	Treatment means
2°C 24 wk	78.8f b	80.0f b	83.2g a	80.7 C
2°C 12 wk- 10°C 12 wk	72.7f a	71.8f a	81.6g a	75.4 A
10°C 12 wk- 2°C 12 wk	74.9f a	76.8f b	81.4g a	77.7 B
10°C 24 wk	71.5f a	72.2f a	81.3g a	75.0 A
Inbred means	74.5F	75.2F	81.9G	

[x]Means in columns followed by the same letter (a to c) and means in rows followed by the same letter (f to g) are not significantly different at the 5% level.

The storage treatments had no significant effect on inbred 661-20, but 2°C for 24 weeks significantly delayed flowering of inbred 2399 more than any other treatment. Either 2°C for 24 weeks or 2°C for the second 12 weeks delayed flowering of inbred 826.

The difference between the flowering dates of inbred 661-20 and the two other inbreds might cause problems for hybrid seed production. A possible solution would be to store inbred 661-20 at 10°C for 24 weeks and inbreds 2399 and 826 at 2°C for 24 weeks so that the flowering dates would be more likely to coincide. This method of altering flowering dates to promote "nicking" was suggested by Atkin and Davis (1954).

Height of the Primary Seedstalk (Table 3)

The height of the seedstalks is important for two reasons: 1) they comprise a major amount of the photosynthetic area for the seed plant and 2) tall seedstalks have a greater tendency to lodge and become tangled with each other making cultural practices difficult. Where hybrid seed is being produced, separation of male and female lines is essential.

The optimum height is not known, but higher seed yields have been associated with medium storage (7° to 12°C) treatments (Jones, 1927; Jones and Emsweller, 1939) and with combination warm-cold treatments (DeMille and Vest, 1976; Van Der Meer and Bennekom, 1969). DeMille and Vest (1976) reported the seedstalks were slightly taller after the combination treatments (2°C 1st half-7°C 2nd half, and 7°C 1st half-2°C 2nd half) than after the 7°C treatment.

In this study, bulbs stored at 10°C for 24 weeks produced the shortest primary seedstalks, while storage at 10°C for 12 weeks

Table 3. Mean height (cm) of the primary seedstalks of 3 onion inbred lines following 4 storage treatments

Storage treatment	Inbred[x] 2399	826	661-20	Treatment means
2°C 24 wk	97.6h c	80.1g ab	66.5f a	81.4 B
2°C 12 wk- 10°C 12 wk	93.0h b	82.7g b	67.4f a	81.0 B
10°C 12 wk- 2°C 12 wk	95.8h bc	81.6g ab	70.4f a	82.6 B
10°C 24 wk	87.2h a	78.3g a	69.1f a	78.2 A
Inbred means	93.4H	80.7G	68.4F	

[x]Means in columns followed by the same letter (a to c) and means in rows followed by the same letter (f to h) are not significantly different at the 5% level.

followed by 2°C for 12 weeks resulted in the tallest primary seedstalks. The latter treatment also produced the highest seed yield. Inbred 2399 produced the tallest primary seedstalks, and inbred 661-20 the shortest.

Inbred 661-20 was not significantly affected by the storage treatments, but 2°C for 24 weeks did result in the shortest primary seedstalks. However, this treatment resulted in the tallest primary seedstalks for inbred 2399 and an intermediate height for inbred 826. The combination treatments resulted in an intermediate height for inbred 2399, but inbred 826 produced the tallest primary seedstalks after storage at 2°C for 12 weeks followed by 10°C for 12 weeks.

Number of Leaves (Table 4)

Storage of the bulbs at 10°C for 24 weeks or at 10°C for the first 12 weeks resulted in the highest number of leaves per plant and this agrees with the findings of DeMille and Vest (1976). Inbred 2399 had the most leaves, inbred 661-20 the least, and inbred 826 an intermediate number.

The storage treatments had no effect on inbred 661-20. For inbreds 2399 and 826, 2°C for 24 weeks resulted in the fewest leaves, while 10°C for 24 weeks resulted in the greatest number and the combination treatments resulted in an intermediate number.

Umbels (Table 5)

Jones and Emsweller (1939) reported bulbs stored at 8° and 12°C resulted in more umbels per plot and a higher seed yield. However, DeMille and Vest (1976) found no significant differences between the number of umbels per plant, but a significantly greater seed yield after the 7°C 1st half-2°C 2nd half treatment.

Table 4. Mean number of leaves per bulb for 3 onion inbred lines following 4 storage treatments

Storage treatments	Inbred[x] 2399	826	661-20	Treatment means
2°C 24 wk	12.9h a	8.9g a	5.1f a	9.0 A
2°C 12 wk- 10°C 12 wk	14.7h b	9.8g ab	4.9f a	9.8 AB
10°C 12 wk- 2°C 12 wk	14.7h b	10.0g ab	5.3f a	10.0 AB
10°C 24 wk	15.5h b	11.3g b	5.3f a	10.7 B
Inbred means	14.4H	10.0G	5.2F	

[x]Means in columns followed by the same letters (a to b) and means in rows followed by the same letter (f to h) are not significantly different at the 5% level.

Table 5. Mean number of umbels per bulb for 3 onion inbred lines following 4 storage treatments

Storage treatment	Inbred[x] 2399	826	661-20	Treatment means
2°C 24 wk	2.61g a	1.48fg a	1.00f a	1.69 A
2°C 12 wk- 10°C 12 wk	3.47g b	1.68f a	1.00f a	2.05 B
10°C 12 wk- 2°C 12 wk	3.12g b	1.38f a	1.00f a	1.83 AB
10°C 24 wk	4.25h c	2.49g b	1.04f a	2.59 C
Inbred means	3.36H	1.76G	1.01F	

[x]Means in columns followed by the same letter (a to c) and means in rows followed by the same letter (f to h) are not significantly different at the 5% level.

In this study a variation in the number of umbels per plant was noted. Storage at 10°C for 24 weeks resulted in the most umbels, while 2°C for 24 weeks or 2°C for the second 12 weeks resulted in the fewest. If 2°C was given for the first 12 weeks, it resulted in an intermediate number. Inbred 2399 produced the most umbels, inbred 826 half as many, and inbred 661-20 only one per bulb.

Inbred 2399 produced the fewest umbels after storage for 24 weeks at 2°C and the most after storage for 24 weeks at 10°C, while the combination treatments resulted in an intermediate number. For inbred 826, exposure to 2°C at any time during storage resulted in the fewest umbels, while 10°C for 24 weeks resulted in one more umbel per bulb. The storage treatments had no effect on inbred 661-20.

Florets

Bulb (Table 6)

Although the storage treatments had no significant effect on the mean number of florets per bulb, the 2°C 12 week-10°C 12 week treatment resulted in the greatest number of florets and the 2°C 24 week treatment the smallest. Individually, inbred 2399 produced the most florets per bulb, followed by inbreds 826 and 661-20.

Storage of inbred 826 at 10°C for 24 weeks or at 10°C for the second 12 weeks resulted in the most florets per bulb. The treatments had little effect on inbreds 2399 or 661-20. However, since 661-20 produced only 1 umbel per bulb, the next section gives a better analysis of the number of florets per bulb for that inbred.

Table 6. Mean number of florets per bulb for 3 onion inbred lines following 4 storage treatments

Storage treatment	Inbred[x] 2399	826	661-20	Treatment means
2°C 24 wk	1303.5h a	843.8g a	504.5f a	883.9 A
2°C 12 wk-10°C 12 wk	1464.0g a	1232.2g b	316.0f a	1004.1 A
10°C 12 wk-2°C 12 wk	1408.8h a	1003.5g ab	467.8f a	960.0 A
10°C 24 wk	1375.5g a	1201.2g b	354.5f a	977.1 A
Inbred means	1388.0H	1070.2G	410.7F	

[x]Means in columns followed by the same letter (a to b) and means in rows followed by the same letter (f to h) are not significantly different at the 5% level.

Umbel (Table 7)

Storage at 2°C for 24 weeks or at 2°C for the second 12 weeks resulted in the greatest number of florets per umbel, while storage at 10°C for 24 weeks resulted in the fewest florets per umbel. Inbred 826 produced the greatest number of florets per umbel.

The treatments had no significant effect on inbred 2399, but inbred 826 produced the fewest florets per umbel after storage at 10°C for 24 weeks. Storage of inbred 661-20 at 10°C for 24 weeks or at 10°C for the second 12 weeks resulted in the fewest florets per umbel (therefore also the fewest florets per bulb since it only produced 1 umbel).

Primary Umbel (Table 8)

Storage at 2°C for 24 weeks or at 2°C for the second 12 weeks resulted in the highest number of florets per primary umbel. Inbred 661-20 produced the fewest florets per primary umbel, inbred 2399 an intermediate number, and inbred 826 the most.

The storage treatments did not significantly affect inbred 2399. Inbred 826 produced the most florets per primary umbel after the combination treatments, while 10°C for 24 weeks resulted in the least florets. Storage of inbred 661-20 at 2°C for 24 weeks or for the second 12 weeks resulted in the most florets per primary umbel.

Secondary Umbel (Table 9)

The treatments had no significant effect on the number of florets per secondary umbel.

Table 7. Mean number of florets per umbel for 3 onion inbred lines following 4 storage treatments

Storage treatment	Inbred[x] 2399	826	661-20	Treatment means
2°C 24 wk	466.0f a	657.5g b	504.5f c	542.7 B
2°C 12 wk- 10°C 12 wk	406.2f a	681.2g b	316.0f a	467.8 B
10°C 12 wk- 2°C 12 wk	451.5f a	703.0g b	467.8f bc	540.8 B
10°C 24 wk	345.0f a	450.2f a	354.5f ab	383.2 A
Inbred means	417.2F	623.0G	410.7F	

[x]Means in columns followed by the same letter (a to c) and means in rows followed by the same letter (f to g) are not significantly different at the 5% level.

Table 8. Mean number of florets per primary umbel for 3 onion inbred lines following 4 storage treatments

Storage treatment	Inbred[x] 2399	826	661-20	Treatment means
2°C 24 wk	525.5f a	715.2g ab	504.5f b	581.7 B
2°C 12 wk- 10°C 12 wk	490.8g a	833.5h b	316.0f a	546.8 AB
10°C 12 wk- 2°C 12 wk	581.5f a	822.0g b	467.8f b	623.8 B
10°C 24 wk	448.8f a	620.0g a	354.5f ab	474.4 A
Inbred means	511.6G	747.7H	410.7F	

[x]Means in columns followed by the same letter (a to b) and means in rows followed by the same letter (f to h) are not significantly different at the 5% level.

Table 9. Mean number of florets per secondary umbel for 2 onion inbred lines following 4 storage treatments

Storage treatment	Inbred[x] 2399	826	Treatment means
2°C 24 wk	437.2	382.5	409.8
2°C 12 wk-10°C 12 wk	374.5	501.0	437.8
10°C 12 wk-2°C 12 wk	366.5	389.8	378.2
10°C 24 wk	313.5	323.5	318.5
Inbred means	372.9	399.2	

[x]Means in columns and means in rows are not significantly different at the 5% level.

Secondary Florets per Bulb (Table 10)

Storage at 2°C for 24 weeks or at 2°C for the last 12 weeks resulted in the fewest secondary florets (florets from all secondary umbels) per bulb. Inbred 2399 produced the most secondary florets per bulb.

Inbred 826 produced the most secondary florets per bulb after storage at 10°C for 24 weeks or at 10°C for the second 12 weeks. The treatments affected 2399 very little.

Summary of the Floret Data

The inbreds responded quite differently from each other. Inbred 661-20 produced only one umbel per bulb and storage at 2°C for 24 weeks or at 2°C for the second 12 weeks resulted in a significantly greater number of florets per umbel and therefore per bulb.

Storage of inbred 826 at 2°C for 24 weeks resulted in 1.48 umbels and the fewest florets per bulb. Storage at 2°C for the first 12 weeks resulted in approximately the same number of umbels (1.68), but a significantly greater number of florets per bulb. If 2°C was given for the second 12 weeks, inbred 826 again produced approximately the same number of umbels (1.38), but an intermediate number of florets per bulb. For the above three treatments, the number of florets per umbel did not vary significantly. The 10°C 24 week treatment resulted in 2.49 umbels per bulb, but this increase of 1 umbel did not increase the total florets per bulb as might have been expected. It simply resulted in significantly fewer florets per umbel. Thus, while the number of umbels per bulb and the number of florets per umbel were interrelated, the storage treatments had a direct effect on each component independently.

Table 10. Mean number of secondary florets per bulb for 2 onion inbred lines following 4 storage treatments

Storage treatment	Inbred[x] 2399	826	Treatment means
2°C 24 wk	778.0g a	128.5f a	453.2 A
2°C 12 wk- 10°C 12 wk	973.2g a	398.5f ab	685.8 AB
10°C 12 wk- 2°C 12 wk	827.5g a	181.5f a	504.5 A
10°C 24 wk	998.2g a	581.2f b	789.7 B
Inbred means	894.2G	322.4F	

[x]Means in columns followed by the same letter (a to b) and means in rows followed by the same letter (f to g) are not significantly different at the 5% level.

This complex interaction was observed for the number of florets per primary umbel also. After storage at 10°C for 24 weeks inbred 826 produced the most umbels per bulb and fewest florets per primary umbel. The combination treatments resulted in approximately 1.5 umbels per bulb, and the most florets per primary umbel. The 2°C 24 week treatment also resulted in approximately the same number of umbels per bulb (1.48), but an intermediate number of florets per primary umbel.

Inbred 2399 produced 4.25 umbels per bulb after the 10°C 24 week treatment while storage at 2°C for 24 weeks resulted in 2.69 umbels. The combination treatments resulted in approximately 3.29 umbels per bulb. Although for inbred 2399 the number of umbels per bulb varied dramatically, the total florets per bulb did not. The florets were simply distributed over the number of umbels.

The storage treatments did not significantly affect the number of florets per umbel or primary umbel for inbred 2399. However, as the number of umbels per bulb increased, the number of florets per umbel or primary umbel decreased.

The number of florets per secondary umbel did not vary significantly for either inbred 826 or 2399. However, when the number of umbels per bulb was the largest, the number of florets per secondary umbel was the smallest.

Atkin and Davis (1954) reported the Excel cultivar showed some differences in the number of florets per umbel according to different storage treatments, but these were not significant. In another experiment they used the cultivar Australian Brown and collected primary umbels. They reported storage treatments had a minimum influence on the number of florets per umbel, but 0°C was significantly

poorer than 10°, 20°C or common storage. This does not agree with the present study and is probably due to the different cultivar used.

Seed Yield

Bulb (Table 11)

The storage treatments did not significantly affect the total seed yield per bulb. The 10°C 12 week-2°C 12 week treatment did result in the best yield and this agrees with earlier studies (DeMille and Vest, 1976; Van Der Meer and Van Bennekom, 1969; Woyke and Manczek, 1965). Inbred 2399 produced the most seed and inbred 661-20 the least.

Umbel (Table 12)

Storage for the first 12 weeks at 10°C followed by 12 weeks at 2°C resulted in a significantly greater seed yield per umbel, while 24 weeks at 10°C resulted in the smallest yield. DeMille and Vest (1976) reported similar results. Storage at 2°C for the first 12 weeks or for 24 weeks had an intermediate effect. Inbred 661-20 produced the least seed per umbel.

Primary Umbel (Table 13)

Storage at 10°C for 12 weeks followed by 12 weeks at 2°C resulted in the highest seed yield per primary umbel, while 10°C for 24 weeks resulted in the lowest yield. Inbred 661-20 produced the smallest amount of seed per primary umbel.

Storage of inbreds 2399 and 661-20 at 10°C for 24 weeks resulted in the lowest yield, while 10°C for the first 12 weeks only resulted in the highest yield. The treatments had less effect on inbred 826.

Table 11. Mean seed yield per bulb (grams) for 3 onion inbred lines following 4 storage treatments

Storage treatment	Inbred[x] 2399	826	661-20	Treatment means
2°C 24 wk	7.8905h	4.6672g	1.9696f	4.8424
2°C 12 wk-10°C 12 wk	9.9568g	4.2232f	2.0608f	5.4136
10°C 12 wk-2°C 12 wk	10.9983g	4.6520f	2.5392f	6.0632
10°C 24 wk	9.3509h	4.6739g	1.1458f	5.0569
Inbred means	9.5491H	4.5541G	1.9288F	

[x]Means in columns and means in rows followed by the same letter (f to h) are not significantly different at the 5% level.

Table 12. Mean seed yield (grams) per umbel for 3 inbred lines following 4 storage treatments

Storage treatment	Inbred[x] 2399	826	661-20	Treatment means
2°C 24 wk	3.2272g b	3.3419g bc	1.9696f ab	2.8462 BC
2°C 12 wk- 10°C 12 wk	3.0886g ab	2.8320g ab	2.0608f b	2.6605 B
10°C 12 wk- 2°C 12 wk	3.6617g b	3.7217g c	2.5392f b	3.3075 C
10°C 24 wk	2.2844g a	2.2060g a	1.1458f a	1.8787 A
Inbred means	3.0655G	3.0254G	1.9288F	

[x]Means in columns followed by the same letter (a to c) and means in rows followed by the same letter (f to g) are not significantly different at the 5% level.

Table 13. Mean seed yield (grams) per primary umbel for 3 onion inbred lines following 4 storage treatments

Storage treatment	Inbred[x] 2399	826	661-20	Treatment means
2°C 24 wk	3.7230g a	3.6769g a	1.9696f ab	3.1232 B
2°C 12 wk- 10°C 12 wk	3.9512g ab	3.4576g a	2.0608f ab	3.1565 B
10°C 12 wk- 2°C 12 wk	4.6855g b	3.9236g a	2.5392f b	3.7161 C
10°C 24 wk	3.1575g a	3.1560g a	1.1458f a	2.4864 A
Inbred means	3.8795G	3.5535G	1.9288F	

[x]Means in columns followed by the same letter (a to b) and means in rows followed by the same letter (f to g) are not significantly different at the 5% level.

Secondary Umbel (Table 14)

Storage at 2°C for 24 weeks or at 2°C for the second 12 weeks resulted in the highest seed yield per secondary umbel. Bulbs stored at 10°C for 24 weeks produced the lowest yields, while those at 10°C for the second 12 weeks produced an intermediate yield. Inbred 2399 produced the most seed per secondary umbel.

Secondary Seed Yield per Bulb (Table 15)

The storage treatments had little effect on the secondary seed yield (yield from all secondary umbels) per bulb. Inbred 2399 produced the most secondary seed per bulb.

Seed Yield Summary

The 10°C 12 week-2°C 12 week treatment resulted in the highest seed yield per bulb, but the number of umbels and florets per bulb was intermediate. Thus, the highest number of umbels per bulb (after the 10°C 24 week treatment) did not increase the seed yield as might have been expected. The 10°C 12 week-2°C 12 week treatment resulted in a high number of florets per umbel and a significantly higher seed yield per umbel. Storage at 10°C for 24 weeks resulted in the fewest florets and lowest seed yield per umbel.

It is apparent the 10°C 12 week-2°C 12 week treatment was most favorable for seed production. The treatment reduced the number of umbels and increased the florets and seed yield per umbel. Therefore, it appears there is an optimum number of umbels and florets per umbel that results in the best seed yield.

Table 14. Mean seed yield (grams) per secondary umbel for 2 onion inbred lines following 4 storage treatments

Storage treatment	Inbred[x] 2399	826	Treatment means
2°C 24 wk	2.8564f a	2.6938f b	2.7751 B
2°C 12 wk- 10°C 12 wk	2.6964f a	1.6553f ab	2.1758 AB
10°C 12 wk- 2°C 12 wk	3.1206f a	2.2823f ab	2.7014 B
10°C 24 wk	2.0027f a	1.0572f a	1.5300 A
Inbred means	2.6690G	1.9221F	

[x]Means in columns followed by the same letter (a to b) and means in rows followed by the same letter (f to g) are not significantly different at the 5% level.

Table 15. Mean secondary seed yield (grams) per bulb for 2 onion inbred lines following 4 storage treatments

Storage treatments	Inbred[x] 2399	826	Treatment means
2°C 24 wk	4.1687g	0.9915f	2.5801
2°C 12 wk-10°C 12 wk	6.0080g	0.7394f	3.3737
10°C 12 wk-2°C 12 wk	6.3128g	0.7259f	3.5194
10°C 24 wk	6.1934g	1.5091f	3.8512
Inbred means	5.6707G	0.9915F	

[x]Means in columns and means in rows followed by the same letter (f to g) are not significantly different at the 5% level.

Weight per Seed

Umbel (Table 16)

The storage treatments had no significant effect on the weight of seeds harvested from umbels. This result agrees with DeMille and Vest (1976).

Primary Umbel (Table 17)

The storage treatments did not affect the mean weight of seeds harvested from primary umbels. Inbreds 2399 and 661-20 had the largest seeds and inbred 826 the smallest.

The 2°C treatments resulted in the heaviest seeds from a primary umbel for 2399 while storage at 10°C for 24 weeks resulted in seeds that were approximately .3 mg lighter. The treatments did not affect inbred 826. For inbred 661-20, storage at 2°C for the first 12 weeks resulted in the heaviest seeds while 2°C for the second 12 weeks resulted in seeds that were .4 mg lighter.

Secondary Umbel (Table 18)

The storage treatments had no significant effect on the weight of seeds harvested from secondary umbels.

For inbred 2399, seeds from primary or secondary umbels weighed the same, but for inbred 826 the seeds from secondary umbels were .4 mg lighter.

Summary

The treatments did not affect the mean weight of a seed. However, the inbreds did respond differently, e.g., the 10°C 12 week-2°C 12 week treatment resulted in the heaviest seeds from the primary umbels for inbred 2399 and the lightest for inbred 661-20. It is apparent

Table 16. Mean weight (mg) of seeds harvested from the umbels of 3 onion inbred lines following 4 storage treatments

Storage treatment	Inbred[x] 2399	826	661-20	Treatment means
2°C 24 wk	4.0g	3.5f	3.8g	3.8
2°C 12 wk-10°C 12 wk	3.9g	3.4f	4.1g	3.8
10°C 12 wk-2°C 12 wk	4.0g	3.5f	3.7fg	3.7
10°C 24 wk	3.7fg	3.5f	3.9g	3.7
Inbred means	3.9G	3.5F	3.9G	

[x]Means in columns and means in rows followed by the same letter (f to g) are not significantly different at the 5% level.

Table 17. Mean weight (mg) of seeds harvested from primary umbels of 3 onion inbred lines following 4 storage treatments

Storage treatment	Inbred[x] 2399	826	661-20	Treatment means
2°C 24 wk	4.0g b	3.5f a	3.8g ab	3.8
2°C 12 wk- 10°C 12 wk	3.9g ab	3.6f a	4.1g b	3.9
10°C 12 wk- 2°C 12 wk	4.0g b	3.5f a	3.7f a	3.7
10°C 24 wk	3.6f a	3.7fg a	3.9g ab	3.7
Inbred means	3.9G	3.6F	3.9G	

[x]Means in columns followed by the same letter (a to b) and means in rows followed by the same letter (f to g) are not significantly different at the 5% level.

Table 18. Mean weight (mg) of seeds harvested from secondary umbels of 2 onion inbred lines following 4 storage treatments

Storage treatment	Inbred[x] 2399	826	Treatment means
2°C 24 wk	4.0g	3.4f	3.7
2°C 12 wk-10°C 12 wk	3.9g	3.2f	3.6
10°C 12 wk-2°C 12 wk	4.0g	2.9f	3.4
10°C 24 wk	3.9g	3.2f	3.6
Inbred means	4.0G	3.2F	

[x]Means in columns and means in rows followed by the same letter (f to g) are not significantly different at the 5% level.

that, to achieve optimum results, the inbreds would have to be handled differently.

Number of Florets that Set Seed

Bulb (Table 19)

Although the storage treatments had no significant effect, storage at 10°C for 12 weeks followed by 2°C for 12 weeks resulted in a greater number of florets that set seed per bulb. Bulbs stored at 2°C for 24 weeks resulted in the poorest set per bulb. Inbred 2399 set the most florets, followed by inbreds 826 and 661-20.

Umbel (Table 20)

The 10°C 12 week-2°C 12 week treatment resulted in the highest set per umbel and the 10°C 24 week treatment the lowest. Inbred 826 set the most florets per umbel.

The treatments had no effect on inbreds 2399 and 661-20, but inbred 826 set more florets per umbel after the 2°C treatments.

Primary Umbel (Table 21)

Although the storage treatments had no significant effect, storage at 10°C for 12 weeks followed by 2°C for 12 weeks resulted in the highest set per primary umbel. Inbred 826 set the most florets.

Secondary Umbel (Table 22)

Storage at 2°C for 24 weeks resulted in the highest number of florets that set seed per secondary umbel, while storage at 10°C for 24 weeks resulted in the lowest. The combination treatments resulted in an intermediate number. Inbred 826 set approximately 100 more florets per secondary umbel than inbred 2399.

Table 19. Mean number of florets that set seed per bulb for 3 onion inbred lines following 4 storage treatments, 1976

Storage treatment	Inbred[x] 2399	826	661-20	Treatment means
2°C 24 wk	652g	703g	274f	543
2°C 12 wk-10°C 12 wk	893g	678g	289f	620
10°C 12 wk-2°C 12 wk	930g	708fg	394f	677
10°C 24 wk	1052g	602f	292f	649
Inbred means	882H	673G	312F	

[x]Means in columns and means in rows followed by the same letter (f to h) are not significantly different at the 5% level.

Table 20. Mean number of florets that set seed per umbel for 3 onion inbred lines following 4 storage treatments, 1976

Storage treatment	Inbred[x] 2399	826	661-20	Treatment means
2°C 24 wk	272f a	530g b	274f a	359 AB
2°C 12 wk- 10°C 12 wk	249f a	550g b	289f a	363 AB
10°C 12 wk- 2°C 12 wk	290f a	522g b	394fg a	402 B
10°C 24 wk	238f a	310f a	248f a	265 A
Inbred means	262F	478G	301F	

[x]Means in columns followed by the same letter (a to b) and means in rows followed by the same letter (f to g) are not significantly different at the 5% level.

Table 21. Mean number of florets that set seed per primary umbel for 3 onion inbred lines following 4 storage treatments, 1976

Storage treatment	Inbred[x] 2399	826	661-20	Treatment means
2°C 24 wk	296f	554g	274f	374
2°C 12 wk-10°C 12 wk	320f	582g	289f	397
10°C 12 wk-2°C 12 wk	376f	607g	394fg	459
10°C 24 wk	336f	422f	264f	341
Inbred means	332F	541G	305F	

[x]Means in columns and means in rows followed by the same letter (f to g) are not significantly different at the 5% level.

Table 22. Mean number of florets that set seed per secondary umbel for 2 onion inbred lines following 4 storage treatments, 1976

Storage treatment	Inbred[x] 2399	826	Treatment means
2°C 24 wk	255f a	467g c	361 B
2°C 12 wk- 10°C 12 wk	222F a	410g bc	316 B
10°C 12 wk- 2°C 12 wk	250f a	286f ab	268 AB
10°C 24 wk	211f a	180f a	196 A
Inbred means	234F	336G	

[x]Means in columns followed by the same letter (a to b) and means in rows followed by the same letter (f to g) are not significantly different at the 5% level.

The treatments had no significant effect on inbred 2399, but storage of inbred 826 at 2°C for 24 weeks or at 2°C the first 12 weeks resulted in a greater set than the other two treatments.

Secondary Florets that Set Seed per Bulb (Table 23)

The storage treatments had no significant effect on the number of secondary florets that set seed per bulb. However, storage at 10°C for 24 weeks resulted in the most secondary florets (florets from all secondary umbels) per bulb and therefore it also resulted in the highest number of secondary florets that set seed per bulb. Inbred 2399 produced the largest number of secondary florets and therefore the highest number that set seed.

Summary

A significantly larger number of florets set seed per umbel after the 10°C 12 week-2°C 12 week treatment. The number of florets that set seed per bulb, per primary umbel, and the secondary florets that set seed per bulb were less affected by the storage treatments.

The treatments had no significant effect on the number of florets that set seed per secondary umbel for inbred 2399. However, storage of inbred 826 at 2°C for 24 weeks or at 2°C for the first 12 weeks resulted in a greater set per secondary umbel.

Number of Seeds per Floret

No significant differences were found. However, the 10°C 24 week treatment resulted in the fewest seeds per floret in every category (Tables 24 through 27). The mean number of seeds per floret per bulb was 2.38.

Table 23. Mean number of secondary florets that set seed per bulb for 2 onion inbred lines following 4 storage treatments, 1976

Storage treatment	Inbred[x] 2399	826	Treatment means
2°C 24 wk	357g	148f	252
2°C 12 wk-10°C 12 wk	573g	96f	334
10°C 12 wk-2°C 12 wk	553g	101f	327
10°C 24 wk	716g	179f	448
Inbred means	550G	131F	

[x]Means in columns and means in rows followed by the same letter (f to g) are not significantly different at the 5% level.

Table 24. Mean number of seeds per floret per bulb for 3 onion inbred lines following 4 storage treatments, 1976

Storage treatment	Inbred[x] 2399	826	661-20	Treatment means
2°C 24 wk	3.17	2.28	2.61	2.68
2°C 12 wk-10°C 12 wk	2.67	2.16	2.80	2.54
10°C 12 wk-2°C 12 wk	2.67	2.24	2.50	2.47
10°C 24 wk	1.77	2.36	1.34	1.82
Inbred means	2.57	2.26	2.31	

[x]Means in columns and means in rows followed by the same letter are not significantly different at the 5% level.

Table 25. Mean number of seeds per floret per umbel for 3 onion inbred lines following 4 storage treatments, 1976

Storage treatment	Inbred[x] 2399	826	661-20	Treatment means
2°C 24 wk	2.80	2.49	2.61	2.63
2°C 12 wk-10°C 12 wk	3.13	2.06	2.80	2.66
10°C 12 wk-2°C 12 wk	2.93	2.38	2.50	2.60
10°C 24 wk	2.12	2.61	1.58	2.10
Inbred means	2.74	2.38	2.37	

[x]Means in columns and means in rows are not significantly different at the 5% level.

Table 26. Mean number of seeds per floret per primary umbel for 3 onion inbred lines following 4 storage treatments, 1976

Storage treatment	Inbred[x] 2399	826	661-20	Treatment means
2°C 24 wk	2.94	2.49	2.61	2.68
2°C 12 wk-10°C 12 wk	3.14	2.14	2.80	2.69
10°C 12 wk-2°C 12 wk	2.93	2.10	2.50	2.51
10°C 24 wk	2.14	2.46	1.48	2.03
Inbred means	2.79	2.30	2.35	

[x]Means in columns and means in rows are not significantly different at the 5% level.

Table 27. Mean number of seeds per floret per secondary umbel for 2 onion inbred lines following 4 storage treatments, 1976

Storage treatment	Inbred[x] 2399	826	Treatment means
2°C 24 wk	2.74	2.29	2.52
2°C 12 wk-10°C 12 wk	3.00	1.74	2.37
10°C 12 wk-2°C 12 wk	2.87	3.68	3.28
10°C 24 wk	1.96	2.00	1.98
Inbred means	2.64	2.43	

[x]Means in columns and means in rows are not significantly different at the 5% level.

V. SUMMARY AND CONCLUSIONS

In 1975 and 1976 three M.S.U. onion inbreds, 661-20, 826, and 2399, were given the following 4 storage treatments: 2°C 24 weeks, 2°C 12 weeks-10°C 12 weeks, 10°C 12 weeks-2°C 12 weeks, and 10°C 24 weeks. Data on seed yield and related factors were collected and the results are summarized below:

1. The 2°C 24 week storage treatment delayed the *emergence* of inbreds 2399 and 826, but 10°C for 24 weeks delayed inbred 661-20.

2. *Flowering* was delayed by storage at 2°C for 24 weeks, while storage at 10°C for 24 weeks or at 10°C for the last 12 weeks resulted in earlier flowering. Storage at 10°C for the first 12 weeks had an intermediate effect.

3. The 10°C 24 week treatment resulted in the shortest *primary seedstalks* and the 10°C 12 week-2°C 12 week treatment the tallest. Inbred 661-20 produced the shortest primary seedstalks after the 2°C 24 week treatment, while inbreds 2399 and 826 produced the tallest.

4. The 10°C 24 week and 10°C 12 week-2°C 12 week treatments resulted in the most *leaves*.

5. For inbreds 2399 and 826, the 10°C 24 week treatment resulted in the most *umbels* per bulb and the 2°C 24 week and 10°C 12 week-2°C 12 week treatments the least. The higher number of umbels did not produce highest number of florets or seed yield per

bulb. The storage treatments had no significant effect on inbred 661-20 and it only produced 1 umbel per bulb.

6. Storage of inbred 661-20 at 2°C for 24 weeks or at 2°C for the second 12 weeks resulted in a significantly greater number of *florets per umbel* (therefore per bulb).

Storage of inbred 826 at 2°C for 24 weeks resulted in 1.48 umbels and the fewest *florets per bulb*. Storage at 2°C for the first 12 weeks resulted in approximately the same number of umbels (1.68), but a significantly greater number of florets per bulb. If 2°C was given for the second 12 weeks, inbred 826 again produced approximately the same number of umbels (1.38), but only an intermediate number of florets per bulb. The 10°C 24 week treatment resulted in 2.49 umbels per bulb. This increase of 1 umbel per bulb did not increase the total florets per bulb, but resulted in significantly fewer *florets per umbel*.

Inbred 2399 produced 4.25 umbels after the 10°C 24 week treatment while storage at 2°C for 24 weeks resulted in 2.69 umbels. The combination treatments resulted in 3.29 umbels per bulb. Although for inbred 2399 the number of umbels per bulb varied dramatically, the total *florets per bulb* did not. The florets were simply distributed over the number of umbels.

7. The *seed yield* per bulb did not vary significantly, but was the highest after the 10°C 12 week-2°C 12 week treatment. This treatment resulted in the highest seed yield per umbel.

8. The storage treatments had no significant effect on the *weight per seed*.

9. A significantly greater number of *florets set seed* per umbel after the 10°C 12 week-2°C 12 week treatment.

10. Although not significant, the fewest *seeds per floret* occurred after the 10°C 24 week treatment.

The storage treatments had no significant effect on the seed yields per bulb. However, the 10°C 12 week-2°C 12 week treatment resulted in the best yield, which agrees with earlier studies (DeMille and Vest, 1976; Van Der Meer and Van Bennekom, 1969). Accompanying this higher seed yield was a high number of leaves per bulb; tall primary seedstalks; the highest seed set and seed yield per umbel; and a high number of florets and seeds per floret per umbel. It appears that all factors were at an optimum level for maximum seed production. Apparently this treatment conditions or programs the bulb to allow (cause?) the optimum development of complexly interrelated morphological factors and leads to a vigorous healthy seed plant and a higher seed yield.

This treatment may approximate the natural environmental conditions from which these onions were domesticated, i.e., a gradually cooling fall, cold winter, and a gradually warming spring.

Future work besides the 4 treatments should include a fifth one: 10°C 8 weeks-2°C 8 weeks-10°C 8 weeks. Since the inbreds responded so differently, in a breeding program it would be necessary to include all inbreds and classify the responses of each one. Then the best storage temperatures could be provided for the highest consistent seed yields.

APPENDIX

Table A-1. Analysis of variance: Effect of bulb storage treatments on days to emergence, days to flowering, height (cm) of the primary seedstalk, the total number of leaves per bulb, and the total number of umbels per bulb, 1975 and 1976 combined

Source	df	Days to Emergence[1]	Days to Flowering	Height of Primary Seedstalk	Leaves/ Bulb	Umbels/ Bulb
Year	1	711.11***	4,074.69***	1,222.08***	1.46ns	1.65***
Block+ Yearx Block	2	7.22ns	26.36ns	2.80ns	2.62ns	.56*
Tmt	3	25.68*	245.56***	123.81***	18.08***	5.62***
Inbred	2	1,834.01***	806.80***	7,543.14***	1,037.51***	69.35***
TxI	6	81.55***	35.45**	102.84***	4.23ns	1.57***
YxT	3	13.46ns	13.71ns	5.17ns	5.54ns	.29ns
YxI	2	78.22***	46.13*	17.41ns	22.50***	1.55***
YxTxI	6	9.43ns	10.93ns	12.71ns	5.11ns	.16ns
ERROR	118	7.31	11.19	16.02	2.82	.16
Total	143					

[x] Mean squares.

* Significant at the 5% level.

** Significant at the 1% level.

*** Significant at the .5% level.

Table A-2: Analysis of variance: Effect of bulb storage treatments on number of florets for 3 M.S.U. onion inbreds, 1975 and 1976 combined

Source	df	Florets/ Primary Umbel[1]	Florets/Bulb	Florets/Umbel
Year	1	6,627.00ns	5,313.02ns	6,302.08ns
Block+ Yearx Block	2	5,075.08ns	32,761.27ns	7,567.50ns
Tmt	3	47,971.00***	31,872.91ns	68,294.81***
Inbred	2	478,621.02***	3,975,794.00***	233,273.69***
TxI	6	18,605.27**	75,293.99*	15,116.74*
YxT	3	4,331.56ns	38,883.74ns	1,754.03ns
YxI	2	30,472.94**	72,206.33ns	40,833.52***
YxTxI	6	2,482.58ns	38,299.56ns	3,027.50ns
ERROR	22	4,692.76	27,310.36	5,015.82
Total	47			

[1]Mean squares.

*Significant at the 5% level.

**Significant at the 1% level.

***Significant at the .5% level.

Table A-3. Analysis of variance: Effect of bulb storage treatments on the number of florets for 2 M.S.U. onion inbreds (826 and 2399), 1975 and 1976 combined

Source	df	Florets/Secondary Umbel[1]	Secondary Florets/ Bulb
Year	1	760.5ns	57545.28ns
Block+Year xBlock	2	2038.56ns	45121.28ns
Tmt	3	20976.88ns	196685.11**
Inbred	1	5512.50ns	2615756.00***
TxI	3	11256.08ns	23676.45ns
YxT	3	3945.58ns	57601.11ns
YxI	1	861.12ns	197977.78*
YxTxI	3	1304.71ns	21183.45ns
Error	14	10405.06ns	35686.07ns
Total	31		

[1]Mean squares.

*Significant at the 5% level.

**Significant at the 1% level.

***Significant at the .5% level.

Table A-4. Analysis of variance: Effect of bulb storage treatments on seed yield of 3 M.S.U. onion inbreds, 1975 and 1976 combined

Source	df	Seed Yield/ Primary Umbel[1]	Seed Yield/ Bulb	Seed Yield/ Umbel
Year	1	7.2988***	1.7953ns	9.9794***
Block+ Yearx Block	2	1.2307*	3.4591ns	1.0256**
Tmt	3	3.0324***	3.4242ns	4.2546***
Inbred	2	17.4667***	239.7620***	6.6560***
TxI	6	.1669ns	2.4262ns	.0666ns
YxT	3	.6838ns	5.0423ns	.6638*
YxI	2	4.9652***	11.5421***	4.9706***
YxTxI	6	.3704ns	1.7762ns	.3172ns
ERROR	22	.2260	1.6761	.1784
Total	47			

[1]Mean squares.

*Significant at the 5% level.

**Significant at the 1% level.

***Significant at the .5% level.

Table A-5. Analysis of variance: Effect of bulb storage treatments on seed yield of 2 M.S.U. onion inbreds (826 and 2399), 1975 and 1976 combined

Source	df	Seed Yield/Secondary Umbel[1]	Secondary Seed Yield/Bulb
Year	1	5.56***	2.70ns
Block+Year xBlock	2	.10ns	2.10ns
Tmt	3	2.65**	2.32ns
Inbred	1	4.46***	175.16***
TxI	3	.32ns	2.28ns
YxT	3	1.62*	3.07ns
YxI	1	10.45***	1.91ns
YxTxI	3	.87ns	2.28ns
Error	14	.41	1.45
Total	31		

[1]Mean squares.

*Significant at the 5% level.

**Significant at the 1% level.

***Significant at the .5% level.

Table A-6. Analysis of variance: Effect of bulb storage treatments on the weight per seed for 3 M.S.U. onion inbreds, 1975 and 1976 combined

Source	df	Weight/Seed[1] Primary Umbel	Weight/Seed Umbel
Year	1	.1636*	.0149ns
Block+Year xBlock	2	.0614ns	.1167*
Tmt	3	.0317ns	.0240ns
Inbred	2	.4798***	.9752***
TxI	6	.1074*	.0706ns
YxT	3	.0686ns	.0944ns
YxI	2	.0670ns	.1346*
YxTxI	6	.0855*	.0653ns
ERROR	22	.0324	.0317
Total	47		

[1]Mean squares.

*Significant at the 5% level.

**Significant at the 1% level.

***Significant at the .5% level.

Table A-7. Analysis of variance: Effect of bulb storage treatments on the weight per seed for 2 M.S.U. onion inbreds (826 and 2399), 1975 and 1976 combined

Source	df	Weight/Seed Secondary Umbel[1]
Year	1	1.4995***
Block+Year xBlock	2	.2762ns
Tmt	3	.1106ns
Inbred	1	4.4708***
TxI	3	.1490ns
YxT	3	.5905***
YxI	1	.5883*
YxTxI	3	.3184*
ERROR	14	.0860
Total	31	

[1]Mean squares.

*Significant at the 5% level.

**Significant at the 1% level.

***Significant at the .5% level.

Table A-8. Analysis of variance: Effect of bulb storage treatments on the number of florets that set seed for 3 M.S.U. onion inbreds, 1976

Source	df	Floret Set/ Primary Umbel[1]	Floret Set/ Umbel	Floret Set/ Bulb
Block	1	782.04ns	1,232.67ns	630.38ns
Tmt	3	14,928.38ns	20,243.00*	19,966.49ns
Inbred	2	133,988.79***	105,569.54***	663,032.38***
TxI	6	4,069.79ns	7,299.04ns	23,471.65ns
ERROR	11	6,748.50	4,550.76	14,832.10
Total	23			

[1]Mean squares.

*Significant at the 5% level.

**Significant at the 1% level.

***Significant at the .5% level.

Table A-9. Analysis of variance: Effect of bulb storage treatments on the number of seeds per floret for 3 M.S.U. onion inbreds, 1976

Source	df	Seeds/Floret[1] Primary Umbel	Seeds/Floret Umbel	Seeds/Floret Bulb
Block	1	.0726ns	.1190ns	.0014ns
Tmt	3	.5870ns	.4272ns	.8786ns
Inbred	2	.5772ns	.3555ns	.2232ns
TxI	6	.2971ns	.3323ns	.2429ns
ERROR	11	.3788	.4121	.4761
Total	23			

[1]Mean squares.

*Significant at the 5% level.

**Significant at the 1% level.

***Significant at the .5% level.

Table A-10. Analysis of variance: Effect of bulb storage treatments on the number of florets that set seed and seeds per floret for 2 M.S.U. onion inbreds (2399 and 826), 1976

Source	df	Floret Set/ Secondary Umbel[1]	Secondary Florets Set/Bulb	Seeds/Floret Secondary Umbel
Block	1	1314.06ns	1.00ns	.0030ns
Tmt	3	19956.73*	25894.50ns	1.1824ns
Inbred	1	40905.06***	701406.25***	.1936ns
TxI	3	13795.23*	20935.08ns	.7638ns
ERROR	7	2422.78ns	6970.28ns	.3574ns
Total	15			

[1]Mean squares.

*Significant at the 5% level.

**Significant at the 1% level.

***Significant at the .5% level.

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