Rest Period Reduction in Non-Stored Onion (*Allium cepa* L.) Sets

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Abstract. Rest period reduction in non-stored onion (*Allium cepa* L.) sets is favored by post-harvest temperatures of 5° and 25°C for periods of 1 to 10 days. A short-term post-harvest temperature of 45°C favored rest period reduction, but periods over 24 hr at 45° did not reduce the rest period. Reduction of sprouting attributable to the 45° storage was more pronounced with the White Portugal cultivar than with Yellow Ebenezer. Zero to 800 rad gamma irradiation (of freshly harvested sets) did not influence time of sprouting but doses from 1,600 to 12,800 rad decreased sprouting. Potassium gibberellate (A_3)(applied as a dip treatment on sets) increased weights of plants grown from sets stored at 5°C for 72 hr before planting. High post-harvest storage temperatures (45°) negated the subsequent growth promoting effects of GA. Application of these findings has resulted in commercial shipments of freshly harvested onion sets under refrigeration.

Onion (*Allium cepa* L.) sets are usually grown from seed during one season, stored over winter and planted the next season for a dry onion crop. The advantage of planting sets as contrasted to seed is that the time from planting to harvest is reduced. Some sets harvested in the Midwest in July and August have been replanted soon after harvest in the Southern U.S. for a green onion crop. Occasionally sets shipped for planting soon after harvest sprouted erractically rendering the Southern green onion crop unprofitable.

Prior investigation (1,2,11,14,15,18) has shown that garlic and onions usually require a post-harvest rest period to enable sprouting. Chives stored at high temperature treatments for short times sprouted faster (16). Heath (9) and Jones and Mann (12) have reviewed temperature effects on formative factors in onion bulbs. There are claims that the rest period of garlic (*Allium sativum*) decreases most rapidly with storage in the 5-10°C temperature range than at higher (20°C) or lower (0°C) temperatures (19). Precooling of Easter lily bulbs in damp peat was recently shown to cause early emergence and flowering (13).

Humidity was shown to have little effect on sprouting but high humidity did increase rooting of onions (25).

Vegis (23) presented an extensive review of rest and dormancy with temperature models for phases or kinds of rest. The first phase of the rest period is "early rest" and the state of the plant organ is in "predormancy." Organs at this stage of development have not completely lost the ability to grow. The ability to grow is dependent on a narrow range of external factors. Growth response to a certain range of external conditions is called "relative" or "conditional dormancy." The next portion of the rest period is "true dormancy" or middle rest. "True dormancy" is a state in which growth or normal growth cannot be resumed whatever the external conditions may be. The internal condition of dormant organs after the completion of "true dormancy" until the state of maximum growth activity is attained is called "postdormancy." Again (as in "predormancy") the organs are in a state of relative or conditional dormancy and within limits of external conditions the organs may start growth again.

Thomas (21) could not find a significant breaking of dormancy with exogenous Gibberellin A_3, Gibberellin $A_{4/7}$, or 1-naphthylacetic acid (NAA), while Clark and Heath (5) found that indoleacetic acid was induced to high levels the week following bulb induction in intact plants. Gibberellin and auxin activity decreased before sprouting and increased as sprouting commenced (21). Treatment of Easter lily with GA was recently found to cause early emergence and flowering (13).

It has recently been suggested that ethylene in the natural internal bulb atmosphere, probably from fungi sources, is a negative factor in sprouting of tulip bulbs (20).

Bulb formation is dependent on temperature and photoperiod (10,24) with incandescent light providing the most positive bulbing responses (24).

Effects of ionizing irradiation on vegetables have usually been studied from the standpoint of sprout inhibition to prolong storage (3,4,17). Dallyn and Sawyer (6,7) eliminated sprouting and prevented subsequent decay of onions at 12,000 rad doses of irradiation (60 Co source). Other studies (4) have shown that 10 to 50 krep[2] promoted short-term onion and walnut sprouting. However, sprouts reached only a 1/2-inch length from these levels of irradiation before death.

Materials and Methods

Field grown onion sets[3] were subjected to various treatments and then planted immediately in soil in the glasshouse of the Drug and Horticulture Field Station of the University of Illinois at Downers Grove in the four years from 1966 to 1969. At least 20 bulbs were included per treatment in each of 3 or 4 replicates. A randomized block design was employed. A 14-hr photoperiod was maintained with incandescent lamps.

Cultivars utilized were Ebenezer (yellow) in 1966, 1968, and 1969 and White Portugal in 1966, 1967, and 1969.

Ionizing irradiation was included as a treatment in only one of two studies performed in 1966. Ebenezer onion sets were planted once a week, for 8 weeks starting 22 days after harvest. The date when 50% of the sets had sprouted (as a measure of dormancy) was recorded. The second study conducted in 1966 consisted of White Portugal onion sets which were field dried for 3 days subjected to 0, 200, 400, 800, 1,600, 3,200, 6,400, or 12,800 rad doses of ionizing irradiation (Cobalt 60 source); samples of sets which had received the various levels of irradiation were then subjected to either a 5°, 25°, or 45°C temperature treatment for 72 hr and then sub-samples from each irradiation and temperature treatment were dipped in 0, 10, 100, or 1,000 parts per million potassium gibberellate (A_3) plus 0.1% Tween 20. Following this treatment regime the samples were planted in a glasshouse soil filled bench. Time of sprouting, and bulb weights at maturity were measured.

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[2]1 rep = approximately .9 rad.

[3]Onion sets were furnished by the Dutch Valley Onion Set Cooperative, South Holland, Illinois.

The effect of potassium gibberellate (A3) was re-evaluated as both a field and post-harvest application in 1967. Potassium gibberellate (A3) was applied at 0, 10, 100, and 1,000 ppm plus 0.1% Tween 20 at 100 gal/A (to run off) to a portion of the physiologically active onions 7 days before harvest. Onions were harvested and subjected to 5°, 25°, or 45°C for 24, 48, or 72 hr. In 1967, 1968, and 1969 when treatment regimes dictated differing storage periods the samples subjected to the shorter storage periods were held at 25°C until the maximum treatment time was attained so that all treatments could be planted in the glasshouse on the same day. Onions untreated with GA in the field were then subjected to a post-harvest dip of 0, 10, 100, or 1,000 ppm of potassium gibberelate (A3) plus 0.1% Tween 20 and planted in a soil-filled bench. Time of sprouting was recorded by successive counts of emerged sprouts.

In 1968, Ebenezer sets were freshly harvested or field dried for 6 days before subjecting to 5°, 25°, or 45°C for 24, 48, or 72 hr. Time of sprouting by successive counts and bulb weights at maturity were recorded.

The 1969 study included both Ebenezer and White Portugal cultivars with 0% and 100% relative humidity storage introduced as a variable. Storage temperatures of 5°, 25°, and 45°C for 1, 2, 3, 5, and 10 days were evaluated. Time of sprouting and bulb weights at maturity were recorded as in previous years.

Data were analyzed by analysis of variance. Where these analyses indicated differences among means the location of the differences were delineated by multiple comparison methods (8). Sprouting trends over time were described by appropriate functions. The value of coefficients for the specific equations employed to generate the curves were determined using a Gompertzian function as described by Tyler and Norris (22).

The 3 factors of interest obtained by these methods and from this function are: (1) the theoretical maximum number of bulbs sprouting; (2) the time in days of the inflection of the curve, that is the time at which the initially increasing sprouting rate starts to decrease and (3) the number of bulbs sprouted at the time of inflection. Where data are indicated as not plotted, sprouting was so minimal that the model yielded no meaningful results (fitted values were less than 1). All curves for which vallid functions were obtained are not included. For the purpose of brevity, representative curves illustrating all salient treatment effects have been selected for discussion.

Results and Discussion

The time required for sprouting of onion sets after planting decreases with increased time in storage prior to planting (Table 1). This phenomenon is reflected in traditional commercial storage practices.

Table 1. Days to 50% sprouted bulbs ('Ebenezer' - 1966) from 3 to 10 weeks of storage.

Weeks after harvest when planted	Days to 50% sprouting[1]
3	32
4	29
5	24
6	17
7	14
8	11
9	10
10	8

[1]40 bulbs per treatment in a 3 replicate, randomized block design. Stored in a 15° 20°C temperature for 0 to 3 weeks and in a 10° to 20°C for 4 to 10 weeks after harvest.

The stage of the rest period dealt with in this manuscript is the early rest or "predormancy" as defined by Vegis (23). Organs at this time have not completely lost the ability to grow. Onion sets were preconditioned for external factor responses (post-harvest temperature treatments) and by pre-harvest (field) conditions to define the narrow range of conditions which would allow "early rest" growth under varying preconditioning environments which occur from year to year. The ability to grow is within a narrow range of external factors and the definition of these factors is discussed in the following paragraphs.

No significant difference in rate of sprouting attributable to gibberellic acid treatments was apparent in 1966 or 1967. However, greater plant weights were apparent in 1966 when bulbs had been dipped in 100 ppm GA with a post-harvest

Table 2. The effect of four potassium gibberelate (A3) dip levels at 3 post-harvest storage temperatures in 1966 ("White Portugal").

Gibberellic acid concentration in ppm (KGA3)	Post-harvest storage for 72 hr (avg wt per mature plant)[1] 5°C	25°C	45°C
0	43.9 b 1	43.8 b	8.2 c
10	39.9 b	37.6 b	4.1 c
100	61.8 a	40.4 b	2.1 c
1000	31.5 b	31.7 b	0.4 c

[1]Those numbers not containing a common letter are significantly different at the 5% acceptance level according to Duncan's New Multiple Range Test.

treatment of 5°,C for 72 hr (Table 2). Neither higher nor lower levels of GA at this temperature, nor any level of GA at the other storage temperatures, had a significant effect on plant weight at harvest. No plant weight differences attributable to GA were found in 1967 from the pre- or post-harvest application of GA.

Temperatur e and irradiation effects on onion rest period in 1966 and 1967 are summarized in Tables 3 and 4. All 5° and 25° post-harvest treatments for 24 to 72 hr had similar sprouting rates as described in Table 3 and Figure 1.

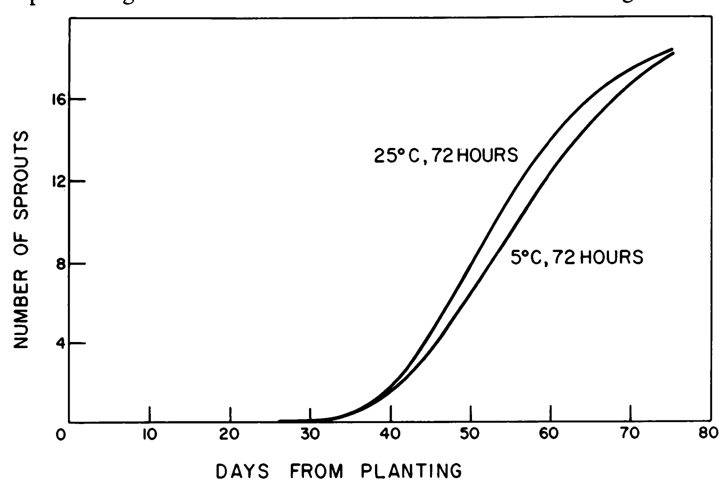

Fig. 1. Number of onions sprouted after 72 hr storage at 5 and 25°C in 1967. (For parameters refer to Table 3.)

Post-harvest storage at 45° for 24 hr did not cause a reduction of sprouting in 1967 (Table 3 and Figure 2). If bulbs stored for 48 hr at 45°, there was a reduction in the number of bulbs sprouted. The 72 hr treated bulbs at 45° had a negligible sprouting rate. The inflection time is less for 45° than for 5° or 25° storage because of a lower number of sprouted sets.

Irradiation levels from 0 to 800 rad did not influence inflection time or number of bulbs at inflection time at 5° or 25° while inflection time was shorter and number of sprouts lower at 45° or 1600 rad or above at 5° and 25° (Table 4 and Fig. 3). Reduction of sprouting was noted from 1,600 to 12,800 rad at 5° and 25°. Depression of sprouting occurred at all irradiation levels for the 45°, 72 hr post-harvest temperature.

No significant differences for sprouting rate between field dried (6 days) and freshly harvested bulbs at all storage

Table 3. Parameters for time of post-harvest temperature treatments in 1967 for 'White Portugal'.

Treatment °C	Hr at storage temperature	Actual no. sprouted	Calculated no. maximum bulbs sprouting	Inflection time in days from time of planting	No. of bulbs sprouted at time of inflection
5	24	18.1	22.5	51.5	8.3
5	48	16.8	20.2	50.6	7.4
5	72	17.1	21.7	52.7	8.0
25	24	16.2	20.1	49.9	7.4
25	48	17.3	22.4	51.9	8.2
25	72	17.2	20.0	49.5	7.3
45	24	16.9	20.4	45.3	7.5
45	48	8.4	10.4	47.9	3.8
45	72		(No plot)		

Data are means of 4 replicates with 20 plants.

Table 4. Parameters for radiation interacted with 72 hr post-harvest storage temperatures in 1966 ('White Portugal').

Treatment °C	Hr at storage rad	Actual no. sprouted	Calculated no. maximum bulbs sprouting	Inflection time in days from time of planting	No. of bulbs sprouted at time of inflection
5	0	12.3	12.6	46.8	4.6
5	200	13.9	15.1	43.6	5.6
5	400	13.1	14.1	42.6	5.2
5	800	13.0	14.8	38.8	5.5
5	1600	8.3	12.7	34.6	4.7
5	3200		(No Plot)		
	to				
5	12800				
25	0	12.5	15.0	40.1	5.5
25	200	10.8	12.5	39.6	4.6
25	400	13.5	13.8	40.6	5.1
25	800	11.7	14.5	37.0	5.3
25	1600	9.5	11.7	36.9	4.3
25	3200		(No Plot)		
	to				
25	12800				
45	0	0.4	0.7	42.2	0.3
45	200	0.4	0.9	36.6	0.3
45	400		(No Plot)		
	to				
45	12800				

Data are means of 4 replicates with 20 plants.

Table 5. Comparison of sprouting values for up to 10 days storage.

Treatment °C	Days at post-harvest temperature	Percent relative humidity during temperature treatment	Cultivar	No. of bulbs sprouted at days from planting[1] 13	38	52
5	1	0	Ebenezer	0.3 c	13.0 ab	17.5 ab
			White Portugal	1.0 bc	15.0 ab	17.0 ab
5	1	100	Ebenezer	0.3 c	12.3 ab	17.8 ab
			White Portugal	0.6 c	14.0 ab	17.3 ab
5	5	0	Ebenezer	0.1 c	12.8 ab	17.8 ab
			White Portugal	0.6 c	14.8 ab	16.0 ab
5	5	100	Ebenezer	0.6 c	14.0 ab	19.0 a
			White Portugal	1.3 bc	14.5 ab	17.0 ab
5	10	0	Ebenezer	0.3 c	13.3 ab	17.0 ab
			White Portugal	0.6 c	13.8 ab	18.0 ab
5	10	100	Ebenezer	0.1 c	16.5 a	18.3 ab
			White Portugal	1.1 bc	12.5 ab	15.8 ab
25	10	0	Ebenezer	0.3 c	15.5 ab	18.8 ab
			White Portugal	0.6 c	15.3 ab	18.0 ab
25	10	100	Ebenezer	0.1 c	13.3 ab	16.5 ab
			White Portugal	0.1 c	12.3ab	16.8 ab
45	1	0	Ebenezer	0.1 c	16.5 ab	18.0 ab
			White Portugal	0.3 c	15.5 ab	18.5 ab
45	1	100	Ebenezer	0.8 c	12.8 ab	16.8 ab
			White Portugal	0.3 c	15.5 ab	18.0 ab
45	5	0	Ebenezer	3.0 ab	14.8 ab	15.5 ab
			White Portugal	3.6 a	9.5 bc	9.8 c
45	5	100	Ebenezer	0.6 c	11.3 abc	13.5 bc
			White Portugal	1.6 abc	4.0 cd	4.0 d

[1]Those numbers not containing a common letter are significantly different at the 1% acceptance level according to Duncan's New Multiple Range Test. Comparisons are between treatments at the same days from planting and not between days from planting. Data are means of 4 replicates with 20 plants.

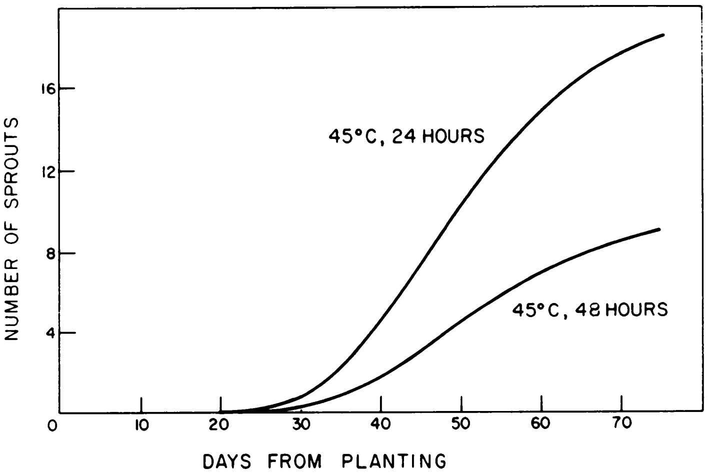

Fig. 2. Number of onions sprouted after 24 and 48 hr storage at 45°C in 1967. (For parameters refer to Table 3.)

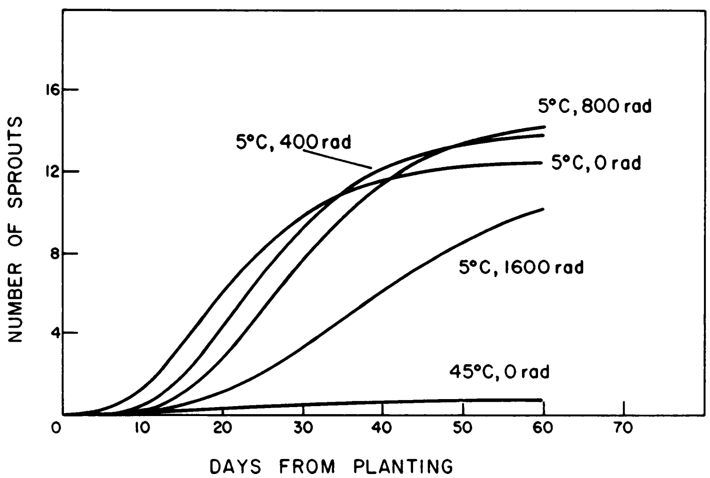

Fig. 3. Number of onions sprouted at 0, 400, 800, 1600 rad when stored at 5°C for 72 hr and 0 rad at 45°C for 72 hr. (For parameters refer to Table 4.)

treatments could be determined in 1968 with the Ebenezer cultivar.

Ebenezer and White Portugal cultivars were evaluated up to 10 days using the 3 post-harvest temperatures to indicate what may occur under prolonged shipment and storage of freshly harvested bulbs from the Midwest to Southern planting sites in August and September. Both cultivars had satisfactory total number and sprouting rates at 5° and 25° for 1, 2, 3, 5, and 10 days at 0% and 100% relative humidity (Table 5). Similar sprouting occurred following storage at 45° for 1 day.

Storage periods over 24 hr at 45° resulted in a reduction of sprouting. The sprouting rate of the White Portugal cultivar is significantly reduced when compared to that of the Ebenezer cultivar at 45° for 5 days. The differential cultivar sprout reduction at 45° helps to explain the commercial problem which stimulated this research because in commercial shipments the White Portugal was usually reported as not sprouting uniformly.

No sprouting occurred for either cultivar stored at 45° for 10 days.

Commercial shipments of freshly harvested, fall planted onion sets are presently refrigerated. Although temperatures of 25°C did not reduce sprouting, it would be difficult to keep temperatures below 45°C in freshly harvested vegetation during late summer or early fall in non-refrigerated shipment because ambient air temperatures are often in the 30° to 40°C range. Further temperature elevations can occur in freshly harvested plant tissue from metabolic processes.

Freshly harvested sets of Ebenezer or White Portugal onions can be expected to produce a satisfactory crop of green onions providing they are not exposed to high temperatures during transit.

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