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STUDIES ON THE VEGETATIVELY PROPAGATED ONIONS CULTIVATED IN FINLAND, WITH SPECIAL REFERENCE TO FLOWERING AND STORAGE

KLAUS AURA

Agricultural Research Centre, Department of Plant Pathology, Tikkurila, Finland

Selostus:

Tutkimuksia Suomessa viljellystä kasvullisesti lisätystä sipulista, erityisesti sen kukinnasta ja varastoinnista

HELSINKI 1963

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I. Vegetatively propagated onion strains grown in Finland

Most of the onions produced in Finland are propagated vegetatively. There are numerous local strains in this country, most of which have been in cultivation for a long time and which may differ greatly from one another in their characteristics. For instance, differences in size, shape, colour and division of bulbs have been noted between the various onion strains (JAMALAINEN 1952). No detailed study has hitherto been made on the characteristics, origin and history of cultivation of these strains, which are generally known as multiplier onions, *Allium cepa* var. *aggregatum* (e.g. JAMALAINEN 1952). The present investigation was mainly concerned with determining the characteristics and taxonomy of certain typical local strains in the most important onion-growing regions of Finland.

Classification of the onion (Allium cepa L.)

HELM (1956) divided cultivated onions into the following four varieties:

1. *Allium cepa* var. *cepa* (*Allium cepa* var. *typicum* Regel p.p.). The plant is a biennial, flowering and producing seed in the second year. Vegetative reproduction is rare, and when it does occur only 1 or 2 daughter bulbs are produced. The shape, size and colour of the bulbs vary considerably. The lower half of the scape has a pronounced swelling. The inflorescences contain many flowers (exception: f. *pauciflorum* (Trev.) Asch. u. Graebn.). The broadened bases of the inner stamen filaments bear two well-defined teeth.

2. *Allium cepa* var. *viviparum* (Metzg.) Alefeld 1866. Bulbils are formed in the inflorescence in addition to or in place of flowers. The scape is uniformly swollen throughout almost its entire length.

3. *Allium cepa* var. *aggregatum* Don 1827. The plant is biennial or perennial. The mother bulbs branch freely, 6—15 daughter bulbs being produced. Flowering is generally poor and the germination of the seeds is low. The bulbs are medium-sized, and roundish but irregular in shape, and somewhat flattened; the external colour of the bulb is usually tan, occasionally white or reddish brown. The scape is short (although longer than the leaves), but only slightly swollen, and it produces few flowers. The broadened bases of the inner stamen filaments do not bear any definite teeth. Reproduction of the plant is exclusively vegetative, i.e. by division of the bulbs. This variety was first described by DON (1827): "bulbis rotundis, depressis, aggregatis, tunicis externis fuscis". ALEFELD (1866) also presented it as a new variety, *Allium cepa solanina*, but his description is similarly very generalized.

4. *Allium cepa* var. *cepiforme* (Don) Regel 1875 (*Allium cepaeforme* Don). The plant reproduces both vegetatively and by seed. The bulbs are small and oblong. The base of the inner stamen filaments is without teeth. In other respects this variety resembles var. *cepa*, but its systematic position is not yet clear.

JONES and MANN (1963), on the other hand, consider that because cultivated onion varieties (var. *aggregatum*, var. *viviparum*), so far as is known, do not represent wild forms or populations but have probably arisen in culture as manmade selections from common onion, they cannot be held as botanical taxons (varieties) within *Allium cepa* (cf. Intern. Code Bot. Nomencl., Art. 28). Thus, they place cultivated onions in three horticultural groups in accordance with the International Code of Nomenclature for Cultivated Plants (Art. 13): 1. Common Onion Group, 2. Aggregatum Group (incl. shallots, see STEARN 1960) and 3. Proliferum Group.

The division of the bulbs has thus been considered an important character for distinguishing different races of *Allium cepa*. The division of onion bulbs is a process involving branching of the stem and development of the lateral shoots formed from the axillary buds into new daughter bulbs; during this process the terminal bud forms a new main bulb. Most of the laterals are evidently initiated during the previous growing season. When growing sets from seed, HARTSEMA (1947) found that the first axillary buds were initiated at the same time as the sheathing leaf bases began to swell. The same phenomenon was also observed by GENKOV (1960 b) in onions grown from sets. During dormancy, new bud primordia may be formed at shoot apices which are in the vegetative condition. This was found to occur to a certain extent in Hytti I onions during studies on inflorescence initiation during storage.

The above-described process of onion division presupposes, however, that the sets are stored at temperatures at which inflorescence initiation does not occur (pp. 17—19). Otherwise, i.e. when the storage temperature is 3—14° C, an inflorescence primordium is formed at almost every shoot apex during the period of storage. In these circumstances the vegetative development of the onion continues from a new bud formed in the axil of the last leaf initial (HEATH and MATHUR 1944, HARTSEMA 1947, ROBERTS and STRUCKMEYER 1952, this study p. 18). In this case, too, the onion divides up, but instead of daughter bulbs, flower stalks are formed; and at the base of these flower stalks a small bulb is formed from the above-mentioned axillary bud. Frequently the inflorescence primordia do not emerge, but instead are destroyed and compressed within the interior of the daughter bulb (pp. 20—22, Fig 9). If the inflorescence primordia of a cool—stored (3—14° C) set are destroyed in this manner, the set appears to have divided normally, but the daughter bulbs are small and oblong in shape as a result of the weak, although rapid, bulbing.

The ability of onions to divide varies among the different cultivars and strains (McCLELLAND 1928, MAGRUDER and HAWTHORN 1935, JONES 1937, MAGRUDER and ALLARD 1937, MAGRUDER *et al.* 1941 a, KAZAKOVA 1954). Large sets or bulbs divide more readily than small ones (THOMPSON 1935, THOMPSON and SMITH 1938, JONES and EMSWELLER 1939, HARTSEMA 1947, LACHMAN and UPHAM 1954, JAMALAINEN 1955, LACHMAN and MICHELSON 1960; cf. BOSWELL 1924 b, JONES 1937, VINCENT 1960). Moreover, growing conditions may have a great effect on the division of bulbs (MAGRUDER and HAWTHORN 1935, JONES 1937, HARTSEMA 1947). MAGRUDER and HAWTHORN (1935) found that freezing temperatures during the growing season led to abundant division. Warm storage of sets results in somewhat more division than cool (3—13° C) storage (p. 34). This effect was also found by THOMPSON and SMITH (1938; cf. also WARNE 1948, BRUINSMA 1957 and KNOBLAUCH 1959 b in their studies on shallot). The phenomenon may be at least partly due to the fact that cool storage accelerates bulbing (pp. 22—23) to such an extent that not all the daughter bulbs are able to separate, but instead many of them remain together within the surrounding leaf bases.

According to HELM (1956), onion cultivars belonging to var. *cepa* do not generally divide, or if they do so, only 1—2 daughter bulbs are formed. Breeding and selection have obviously resulted in an increase in the proportion of non-dividing onions in the populations, since these are preferred on account of their uniform round shape (cf. KRICKL 1943, DOMOKOS 1944). As has been mentioned above, however, division depends to a great extent upon the size of the onion set. On the basis of numerous European and American investigations on seed production in onions (JONES 1928, MILLER 1933, JONES 1937, JONES and EMSWELLER 1939, KRICKL 1943, JONES *et al.* 1949, ATKIN and DAVIS 1954, HARTSEMA and LUYTEN 1955, VINCENT 1960), it can be concluded that the mature bulbs used for seed production usually contain 3—6 axillary buds besides the terminal bud. According to JONES (1937), some cultivars produce as many as 20 flower stalks per plant. Under varm growing conditions, the mother bulbs may produce a cluster of daughter bulbs instead of flower stalks (MILLER 1933, JONES *et al.* 1949, KRICKL 1951). The numbers of daughter bulbs formed is therefore not a reliable character for distinguishing different varieties or groups of *Allium cepa.* The relative size of the set is an important factor to be taken into consideration at the same time.

Material and methods

During the years 1957—62, numerous trips were made under the auspices of the Department of Plant Pathology to the most important areas in Finland where vegetatively propagated onions are cultivated (Fig. 1). On these trips onion material representing the most typical strains was collected for cultivation trials, which were carried out initially at Tikkurila (near Helsinki) and later also at Lohja (in southwestern Finland). The following tabulation shows the different strains which were tested annually at the two trial locations. In the trial area at Tikkurila the soil type was sandy and at Lohja heavy clay. The numbers denoting the different strains are explained in Table 1. In 1962, the strain Gatersleben (var. *aggregatum*, No. 28) was provided by Dr. Johannes Helm (Institut für Kulturpflanzenforschung der Deutschen Akademie der Wissenschaften zu Berlin).

	Tikkurila	Lohja
1957	1	—
1958	1	—
1959	1,3	—
1960	1,3 — 5	1,3 — 5
1961	1,3 — 5	1 — 27
1962	—	2 — 31

The evaluations of the characteristics of the different strains were based mainly on the results of the cultivation trials but partly also on observations made during the trips as well as on the results of storage trials. Most of the onion strains (Nos. 2, 6—27) were included in the trials for only two years and some of them for only one year (Nos. 28—31). It is therefore evident that a complete study of the characteristics of the various strains was out of the question. The evaluation of flowering tendency was based mainly on the results obtained in the cool summer of 1962 (cf. Table 4). The morphological features of the flowers were determined for only a few of the strains (Nos. 1, 2, 4, 5, 7, 21, 26 and 29). The best-known strains are Nos. 1 and 3—5, which have been included in the trials for the longest time.

Observations on bulb division were made principally in the 1962 trials at Lohja; two strains (Nos. 1 and 3) had been studied in this respect at Tikkurila in 1961. Most of the strains (Nos. 2, 4—27) had thus been grown for two consecutive years under the same conditions. The sets (strains 2, 4—27, entire crop of the previous year) were divided into three size classes, providing that there was sufficient material. In each size class there were 6—25 sets; if the number of sets was less than 10, the results are given in parentheses. The data in Table 1 on the size of the sets used in the division trials thus give a clear picture of the bulb size of the particular onion strain concerned. In the case of the large-sized strain Juva II (No. 4), however, the largest sets spoiled during storage, with the result that the bulbs in the third size class (73 g) actually represent middle-sized sets.

A very characteristic feature of any given onion strain was found to be the ratio between the set weight (in grams) of the largest size class and the division of this class (ratio w/d). This ratio was determined for all the strains for which there was sufficient material.

Results and discussion

Features which were common to almost all the onion strains studied included the usually large size of the flower stalk (over 1 m), the pronounced swelling in its lower half, the abundance of flowers per inflorescence and the relatively good

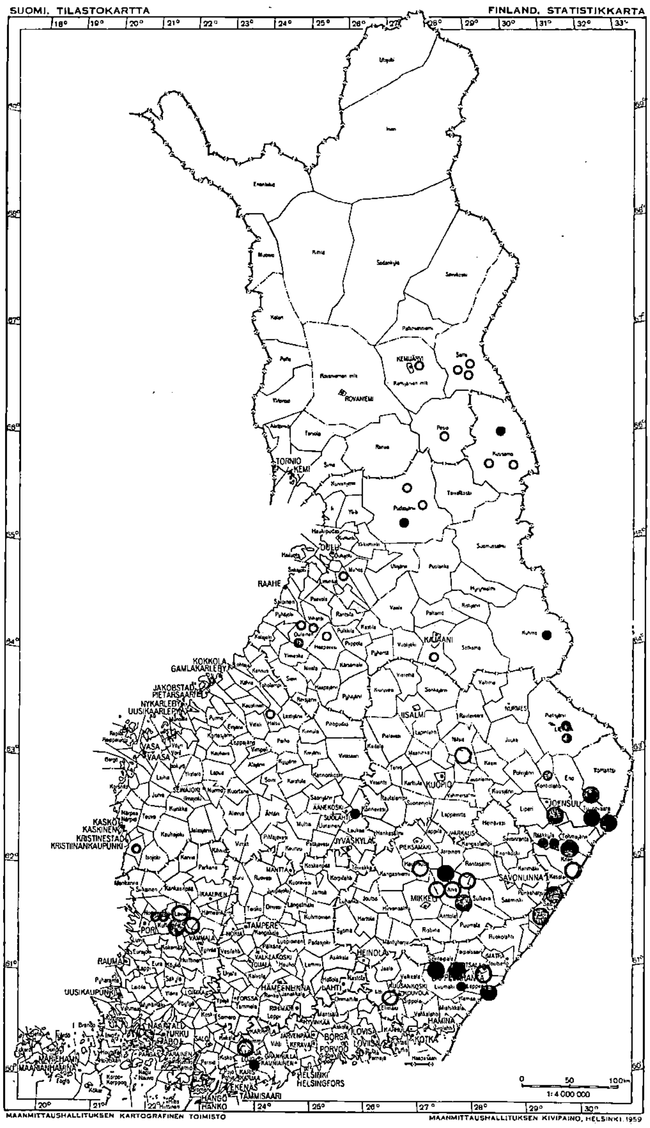

Fig. 1. Distribution of South Finnish and North Finnish onion strains according to investigations and observations made in 1957—1962. Large circles: South Finnish strains; small circles: North Finnish strains; solid circles: samples of strain in cultivation trials.

Kuva 1. Eteläsuomalaisten ja pohjoissuomalaisten sipulikantojen levinneisyys vv. 1957—1962 suoritettujen tutkimusten ja havaintojen mukaan. Suuret ympyrät: eteläsuomalaisia sipulikantoja; pienet ympyrät: pohjoissuomalaisia sipulikantoja; täytetyt ympyrät: sipulikannasta näyte viljelykokeissa.

seed setting. A distinct correlation was observed between the bulb size and division among the various strains: the largest-bulbed strains divided the least, whereas the smallest-bulbed strains underwent the most division (Fig. 2). In general, the strains which produced the largest bulbs also had the longest leaves. *Within* any strain, the relation between size and division of bulbs was the opposite of that *between* strains: large bulbs divided the most and small bulbs the least (Table 1).

On the basis of their bulb size and ability to divide, the onion strains investigated were found to be of two main types: large-sized, poorly dividing strains and small-sized, abundantly dividing strains (Table 1, Fig. 2). In regard to their geographical distribution, these two groups could be termed the South Finnish and the North Finnish onion strains (Fig. 1).

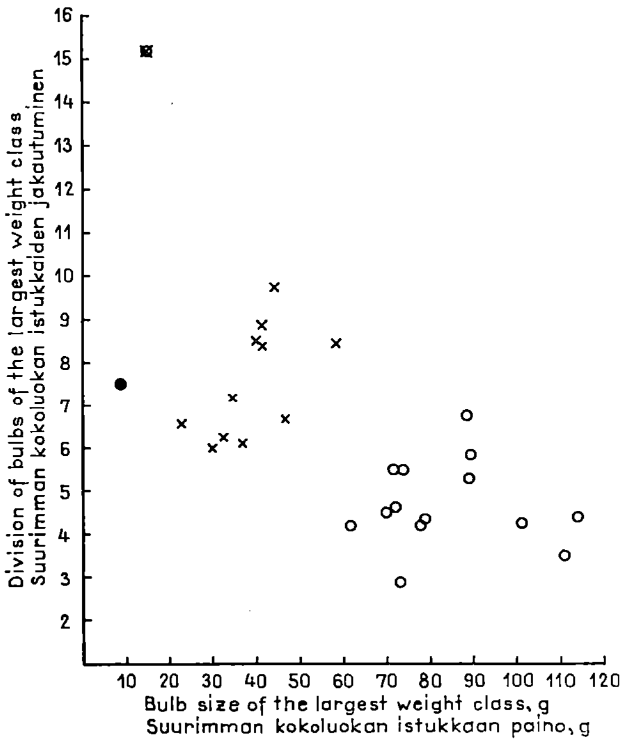

Fig. 2. Correlation between set size and division (in the largest weight class) among the different onion strains. o = South Finnish onion strains; × = North Finnish onion strains; ● = Gatersleben; ▪ = Lohja.

Kuva 2. Sipulin koon ja jakautumisen (suurimman kokoluokan istukkaiden) riippuvuus eri sipulikantojen välillä. o = eteläsuomalaiset sipulikannat; × = pohjoissuomalaiset sipulikannat; ● = Gatersleben; ▪ = Lohja.

The South Finnish onion strains are characterized by a relatively meagre division: large-sized sets (over 60 g) usually produce 3—8 daughter bulbs, but small sets (10—25 g) in many cases do not divide at all (Table 1). These strains have large bulbs, usually weighing from 70 to 200 g. The strain Juva II has the largest (Fig. 3), some of the bulbs weighing nearly 400 g. The most abundantly dividing strain in the 1962 trials was Tuupovaara III; it also had large-sized bulbs, the biggest weighing almost 250 g. The ratio w/d in the South Finnish strains was found to be 13.3—31.7 (Table 1).

The South Finnish onion strains form a heterogeneous group and may differ greatly one from the other. For instance, characteristics such as flowering tendency and earliness vary considerably. The earliest strains include Lemi and Juva II, and among the latest are Hytti I and Juva I. The teething at the base of the inner filaments was found to differ among the strains studied. In the strain Lemi the teeth were almost always distinct, while in Hytti I there were no teeth at all. The teething in the strains Juva II and Saari I was irregular.

The centre of cultivation of South Finnish onion strains is clearly in Southeast Finland (Fig. 1), which is the region where the cultivation of Finnish vegetatively propagated onions in general is concentrated. In the northern parts of the country these strains were not encountered, with the exception of certain experimental plantings.

The most freely dividing South Finnish strains are apparently similar to the Hungarian strains described by DOMOKOS (1944), which produce 3—8 daughter bulbs and which this worker has placed in the class var. *aggregatum.*

The North Finnish onion strains constitute a very uniform group. Their flower stalks are somewhat shorter than those of the South Finnish onion strains. They divide abundantly: large sets (over 40 g) produce 6—15 (—20) daughter bulbs, medium-sized (15—30 g) 4—7 and small sets (under 10 g) produce 2—3 daughter bulbs. In general, the bulbs of these North Finnish strains are relative small in size, weighing 25—70 g. The largest-bulbed strain is Pielisjärvi II (Fig. 3). The ratio w/d in the North Finnish strains was found to be 3.5—6.9 (Table 1). The shape and external colour of the bulbs vary to some extent. The commonest strains are those with oblate and tan-coloured bulbs (Nos. 15, 18, 24, 26, 27). In response to cool growing season, there is generally a pronounced tendency to flower. In all of the strains investigated (Nos. 2, 21 and 26) the bases of the inner stamen filaments bore teeth. The North Finnish strains are all about equally early (the latest is Pielisjärvi II); in this respect they correspond to the southern strains Lemi (No. 5) and Juva II (No. 4).

The best-known areas of cultivation of North Finnish onion strains are the communes of Kuusamo, Pudasjärvi and Oulainen. The strains grown in these communes appear to resemble one another in their most important characteristics (Table 1). Similar strains, some of which may have globe-shaped bulbs and an external colour ranging from reddish to yellowish, are cultivated in

Table 1. Onion strains tested by the Department of Plant Pathology and their most important characteristics
Taulukko 1. Kasvitautien tutkimuslaitoksen kokeissa olleet sipulikannat ja niiden tärkeimmät ominaisuudet

Strain and origin *Sipulikanta ja sen alkuperä*	No. *N:o*	Form of bulb *Sipulin muoto*	Colour of bulb *Sipulin kuoren väri*	Size of bulb (1—5) *Sipulin koko (1—5)*	Set weight and division *Sipulin jakautuminen*	Ratio w/d *suhde p/j*	Flowering tendency (1—5) *Kukkimis-taipumus (1—5)*	Special features *Erikoisominaisuuksia*
Parikkala	14	Round *Pyöreä*	Yellow *Keltainen*	4	111 g: 3.5	31.7	1	
Saari II; Saari, Kirjavala	8	Round *Pyöreä*	Yellow *Keltainen*	4	114 g: 4.4 64 g: 3.0 24 g: 2.3	25.9	4	
Juva II; Juva, Vuorenmaa	4	Round *Pyöreä*	Tan *Kellanruskea*	5	73 g: 2.9 40 g: 2.1 21 g: 1.2	25.2	3—4	Especially large plants *Kasvit erittäin suurikokoisia*
Saari I; Saari, Kesusmaa	7	Round *Pyöreä*	Tan *Kellanruskea*	4	101 g: 4.3 46 g: 2.7 17 g: 1.5	23.5	1—2	
Pyhäselkä; Pyhäselkä, Hammaslahti	19	Round *Pyöreä*	Tan *Kellanruskea*	4	79 g: 4.2 47 g: 2.8 19 g: 1.1	18.8	1—2	Late *Myöhäinen*
Kitee; Kitee, Juurikka	22	Round *Pyöreä*	Yellow *Keltainen*	4	79 g: 4.3 47 g: 2.8 19 g: 1.1	18.4	3	Late *Myöhäinen*
Juva I; Juva, Koikkala	3	Round *Pyöreä*	Tan *Kellanruskea*	4	89 g: 5.3 41 g: 3.4 20 g: 1.9	16.8	2—3	Late; susceptible to virus disease *Myöhäinen; virustaudin arka*
Hytti I; Lappee, Hytti	1	Round *Pyöreä*	Yellow *Keltainen*	3	70 g: 4.5 47 g: 3.3 15 g: 2.3	15.6	4	Late; susceptible to virus diseases; often "yellow leaf tips"; no teeth at base of inner filaments; rather poor cultivation qualities *Myöhäinen; virustaudin arka; suuri taipumus "keltakärkisyyteen"; sisempien palhojen tyvellä ei ole hampaita; viljelyarvo heikohko*
Savitaipale II; Savitaipale, Välijoki	12	Roundish-flattened *Pyöreän litteä*	Yellow *Keltainen*	3—4	90 g: 5.9 48 g: 4.3 25 g: 2.9	15.3	3—4	

Tuupovaara I; Tuupovaara, Eimisjärvi	9	Flattened-roundish *Litteänpyöreä*	Orange *Punakeltainen*	3—4	(72 g: 4.7)	(15.3)	1—2	Late *Myöhäinen*
Lemi; Lemi, Uimi	5	Flattened *Litteä*	Red *Punainen*	3	62 g: 4.2 26 g: 2.9 10 g: 1.9	14.8	1	Leaves bluish-green, short, sturdy; yield moderate; very good keeping qualities; relatively resistant to virus disease *Lehdet sinivihreät, lyhyehköt, tanakat; satoisuus keskinkertainen; säilyvyys eritt. hyvä; suhteellisen virustaudin kestävä*
Tuupovaara II; Tuupovaara, Eimisjärvi	10	Round *Pyöreä*	Yellow *Keltainen*	4	74 g: 5.5 35 g: 3.4 15 g: 2.3	13.5	1—2	Late *Myöhäinen*
Tuupovaara III; Tuupovaara, Öllölä	11	Round *Pyöreä*	Tan *Kellanruskea*	4	89 g: 6.7 55 g: 4.8 22 g: 2.9	13.3	2—3	Late *Myöhäinen*
Lavia; Lavia, Pesinmaa	6	Round *Pyöreä*	Tan *Kellanruskea*	3	(72 g: 5.5)	(13.1)	4	
Pielisjärvi I; Pielisjärvi, Tiensuu	20	Round *Pyöreä*	Red *Punainen*	2—3	46 g: 6.7 29 g: 4.9 17 g: 2.9	6.9	2—3	
Pielisjärvi II; Pielisjärvi, Tiensuu	21	Flattened-roundish *Litteän-pyöreä*	Yellow *Keltainen*	2—3	59 g: 8.5 35 g: 7.2 17 g: 4.7	6.9	1—2	
Oulainen; Oulainen, Matkaniva	24	Flattened *Litteä*	Tan *Kellanruskea*	2	37 g: 6.1 22 g: 4.4 10 g: 2.0	6.1	4	Good keeping qualities *Hyvä säilyvyys*
Rääkkylä II; Rääkkylä, Nieminen	18	Flattened *Litteä*	Tan *Kellanruskea*	2	33 g: 6.2 19 g: 4.5 9 g: 2.7	5.3	3—4	
Suolahti; (Lohja, Karstu)	15	Flattened *Litteä*	Tan *Kellanruskea*	2	30 g: 6.0 18 g: 3.6 10 g: 2.2	5.0	4—5	

Table 1 (cont.) — *Taul. 1 (jatkoa)*

Strain and origin *Sipulikanta ja sen alkuperä*	No. *N:o*	Form of bulb *Sipulin muoto*	Colour of bulb *Sipulin kuoren väri*	Size of bulb (1–5) *Sipulin koko (1–5)*	Set weight and division *Sipulin jakautuminen*	Ratio w/d *suhde p/j*	Flowering tendency (1–5) *Kukkimistaipumus (1–5)*	Special features *Erikoisominaisuuksia*
Kuhmo; Kuhmo, Alavieksi	31	Flattened-roundish *Litteänpyöreä*	Red *Punainen*	2	42 g: 8.4 32 g: 7.9 27 g: 6.5	5.0	3—4	
Hytti II; Lappee, Hytti	2	Flattened *Litteä*	Orange *Punakeltainen*	2	35 g: 7.2 11 g: 4.0 4 g: 1.8	4.9	1—2	Leaves pale green, flattened; short flower stalk *Lehdet vaalean vihreät, litteät; kukintovana lyhyt*
Pudasjärvi; Pudasjärvi, Pärjänsuo	26	Flattened *Litteä*	Tan *Kellanruskea*	2	42 g: 8.9 22 g: 7.2 9 g: 2.9	4.7	4—5	Good keeping qualities *Hyvä säilyvyys*
Kuusamo; Kuusamo, Suininki	27	Flattened *Litteä*	Tan *Kellanruskea*	2	40 g: 8.5 21 g: 5.4 11 g: 2.2	4.7	3—4	Good keeping qualities *Hyvä säilyvyys*
Kontiolahti; Kontiolahti, Lehmo	16	Flattened *Litteä*	Tan *Kellanruskea*	2	45 g: 9.7 23 g: 5.8 10 g: 3.2	4.6	4	
Rääkkylä I; Rääkkylä, Nieminen	17	Flattened *Litteä*	Red *Punainen*	2	23 g: 6.5 9 g: 3.1	3.5	2—3	
Gatersleben	28	Flattened *Litteä*	Tan *Kellanruskea*	1	8 g: 7.5 3 g: 3.2	1.1	(1)	Flower stalk short, delicate, only slightly swollen; few flowers; small lumps at base of inner filaments; leaves delicate *Kukinto lyhyt, hento, harvakukkainen, vana vain lievästi pullistunut; sisempien palhojen tyvellä pienet kyhmyt; lehdet hennot*
Lohja; Lohja, Lehmijärvi	29	roundish-oblong (shallot type) *Epäsäännöllisen pyöreä*	Tan *Kellanruskea*	1	15 g: 15.2	1.0	(1)	Flower stalk rather short, only slightly swollen; few flowers; small lumps at base of inner filaments; leaves delicate *Kukinto lyhyehkö, harvakukkainen, vana vain lievästi pullistunut; sisempien palhojen tyvellä pienet kyhmyt; lehdet hennot*

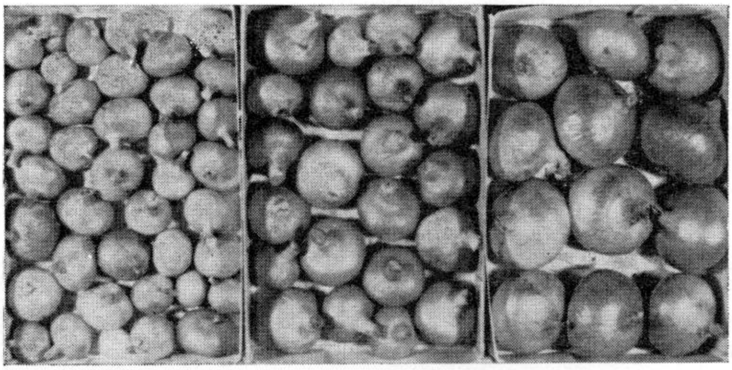

Fig. 3. Finnish onion strains. From left to right: Pudasjärvi, Pielisjärvi II and Juva II. The size of the box: 21×30 cm.

Kuva 3. Suomalaisia sipulikantoja. Vasemmalta: Pudasjärvi, Pielisjärvi II ja Juva II.

Kainuu, certain communes in North Karelia and North Satakunta and in small areas throughout practically the entire country.

The North Finnish onion strains apparently represent forms belonging to the potato onion (Aggregatum group). Onion strains probably similar to these strains are widely cultivated in the northern regions of the Soviet Union (cf. Kazakova 1953). Kazakova (1953, 1954) mentions that, as a result of selection, sexual reproduction in these vegetatively propagated strains has been weakened; far fewer flower stalks are formed than in the strains propagated from seed, and such stalks are short, having a length of only 25—80 cm.

The strain Lohja (No. 29), which has a small-sized bulb (10—25 g) and especially abundant division, forms a group on its own. Flowering of this strain is poor also after storage at 9—13° C. Dissections in 1963 showed that very few inflorescences were initiated at this temperature (about 10 %; cf. Fig. 4). The same was found in the case of the strain Gatersleben (No. 28). The ratio w/d of the strain Lohja is as low as 1.0. This strain is apparently similar to those assigned by Domokos (1944) to *Allium cepa* var. *ascalonicum*, by Helm (1956) to *Allium cepa* var. *aggregatum* and by Jones and Mann (1963) to shallot (Aggregatum group). However, the var. *aggregatum*-type of Helm has bulbs of potato-onion type, although small. The ability of the bulbs to divide has been regarded as the most important characteristic of var. *aggregatum* (Don 1827, Alefeld 1866, Bailey 1949, Helm 1956). It seems probable that this variety and especially true shallots are able to form new laterals early in the growing season (cf. Genkov 1960 a, b). In shallot plants early developed laterals may separate as individual bulbs already during the same season.

Results of the cultivation trials with Finnish local onion strains show that they form a uniform series, ranging from weakly dividing strains (non-dividing in the case of small sets) to very abundantly dividing strains (Fig. 2). Similar observations have also been made by DOMOKOS (1944), BACKER (1951) and KAZAKOVA (1954). DOMOKOS (1944) considered that one of the extreme types of *Allium cepa* is the abundantly dividing shallot (var. *ascalonicum*). The other extreme he held to be the non-dividing *Allium cepa*. As an intermediate type DOMOKOS (1944) described an onion race producing 3—8 daughter bulbs (var. *aggregatum*). BACKER (1951) divided *Allium cepa* into two varieties var. *cepa* and var. *ascalonicum*, which are united by intermediate forms. KAZAKOVA (1954), however, does not separate *Allium cepa* races into different taxons, even though they belong to extreme types in regard to their division of bulbs. — According to BATTAGLIA (1957), both typical *Allium cepa* and shallot have the same karyotype.

The onion strains studied in the present work were differentiated into two main groups: the large-sized, weakly dividing South Finnish strains and the small-sized, abundantly dividing North Finnish strains. The lack of distinct intermediate types was partly due to the relatively small amount of experimental material, but it was also evidently a result of selection of the growers, who are mainly interested in two characteristics: large size of bulbs or abundant division. Other factors, too, have influenced selection. For example, the medium-sized Lemi strain, which is widely cultivated in the commune of Lemi, is weak-flowering and has good keeping qualities, and its prevalence is due to these favourable qualities.

Origin of vegetatively propagated onion strains. In the Soviet Union, especially in its northern regions, there is wide-spread cultivation of vegetatively propagated onions (KAZAKOVA 1953, 1954). Cultivated onions were first introduced into Russia from Central Europe in the twelfth century (KAZAKOVA 1953). This original onion material was initially seed-propagated, but from it have developed the vegetatively propagated North Russian local strains (KAZAKOVA 1954). These latter strains differ from the original forms, according to this same worker, principally in their more abundant division and weaker sexual reproduction.

No detailed study has been made on the origin and history of cultivation of the vegetatively propagated onions grown in Finland. However, it is definitely known that at the end of the last century Russian monks brought with them a good strain of onion to Kuusamo, where its cultivation became established and evidently also spread to other locations in North Finland (PARVELA 1923, 1930, JAMALAINEN 1952).

According to LUNDEN (1921), almost all the vegetatively propagated onions in Finland are of Russian origin. This onion, to which he gave the name potato onion (*Allium cepa solanina*), was imported into this country from Russia in large amounts before the First World War, to be used in planting. These sets, according to LUNDEN (1921), were grown from seed in South Russia and were brought to Finland as one-year-old sets. Seed was produced by growing such sets into large-sized onions, which yielded seed in the following year. Later, onion seed and sets were imported into Finland from many other countries, principally from Holland, Germany, Denmark, Hungary and Czechoslovakia.

It is evident that the majority of the onions at present grown in Finland have their origin in the imports from Russia before the First World War. The present-day local strains were probably developed from the original seed-propagated material as a result of selection by the growers, in the same manner as the North Russian strains. According to KAZAKOVA (1954), any seed-propagated, weakly dividing strain of *Allium cepa* can be induced to reproduce vegetatively by using large-sized, heat-stored sets and by selecting the most profusely dividing onions for further propagation.

The similarity between most of the North Finnish onion strains (e.g. Kuusamo, Pudasjärvi, Oulainen) indicates a common origin (cf. PARVELA 1923, 1930, JAMALAINEN 1952). On the other hand, the lack of uniformity among the South Finnish strains appears to suggest different origins. Most of these strains, too, were probably brought to this country from Russia. Some of these strains hardly differ at all from seed-propagated onions. The largest and most weakly dividing South Finnish strains were probably introduced into this country from Central Europe. According to information obtained by the writer, many Finnish growers have developed their "own" vegetatively propagated onion strain from commercial seed or from seed-grown sets.

Summary

The characteristics of 27 local, vegetatively propagated Finnish onion strains (*Allium cepa* L.) were determined. The evaluations were based mainly on cultivation trials.

A definite correlation was observed between set size and division into daughter bulbs among the different local strains: the large-sized strains divived poorly, while the small-sized strains produced abundant new bulbs. The strains investigated were found to be distributed into two main groups: the large-sized, weakly dividing South Finnish strains and the small-sized, profusely dividing North Finnish strains.

Most of the local Finnish onion strains are presumed to have developed from originally seed-propagated onions introduced from Russia.

II. Inflorescence initiation and emergence

There are two phases in the course of development leading to flowering in the onion: the initiation of inflorescence primordia and their subsequent emergence (e.g. HEATH and MATHUR 1944, HARTSEMA 1947).

Inflorescence primordia in the onion are usually initiated during the dormant period or shortly after planting (JONES and BOSWELL 1923, JONES 1924, BOSWELL 1924 b, JONES and EMSWELLER 1933, 1936, 1939, HEATH and MATHUR 1944, HARTSEMA 1947). The temperature is the most important external factor controlling inflorescence initiation (HEATH and HOLDSWORTH 1948, HOLDS-

WORTH and HEATH 1950). Such initiation is stimulated by temperatures in the range 5—15° C and is prevented by both low (under 1° C) and high (over 17° C) temperatures (HEATH and MATHUR 1944, HARTSEMA 1947, HOLDSWORTH and HEATH 1950, KAZAKOVA 1954). The day length was found to have no effect on inflorescence initiation (HEATH and HOLDSWORTH 1943, HOLDSWORTH and HEATH 1950); other workers found it to have only a slight effect (SCULLY *et al.* 1945, WOODBURY 1950). An inflorescence primordium can be initiated in an onion set only when the latter has reached a certain minimum size (HEATH and MATHUR 1944, HOLDSWORTH and HEATH 1950).

The emergence of the inflorescence primordium (the elongation of the scape) is greatly affected by the external conditions of temperature and day length. Relatively low temperatures (10—15° C) promote inflorescence emergence, whereas high temperatures (above approx. 26° C) prevent it completely (HEATH and MATHUR 1944; cf. THOMPSON and SMITH 1938, WOODBURY 1950). Long days have been found to stimulate the elongation of the scape (HEATH and HOLDSWORTH 1943, HOLDSWORTH and HEATH 1950; cf. THOMPSON and SMITH 1938, SCULLY *et al.* 1945, WOODBURY 1950, ROBERTS and STRUCKMEYER 1952). A great restraining effect on inflorescence emergence is caused by bulbing (HEATH and MATHUR 1944). Thus, the simultaneous action of long day and high temperature accelerates bulbing (THOMPSON and SMITH 1938, HEATH 1943 b) and as a result suppresses flowering (HEATH 1943 b). The fact that a bulb or set has produced inflorescence initials does not necessarily mean that the plant will ultimately flower.

In the present investigation, studies were made to determine the effect of various storage temperatures on both the initiation and the emergence of inflorescence primordia in large-sized onion sets (40—60 g), which are those most commonly used in Finland.

Material and methods

In the studies on inflorescence initiation during storage, the onion strain Hytti I (Table 1) was used. After curing for three weeks at 24—28° C, the sets were placed in five different storage chambers at temperatures of —1°, 3—5°, 9—13°, 21° and 31° C. Storage began on 12. 10. 1960.

In order to determine the time of inflorescence initiation at the above-mentioned temperatures, analyses beginning on 15. 11. 1960 were made at monthly intervals and even more frequently at the end of the storage period. The leaf bases and foliage leaf initials surrounding the apical meristem were removed with a scalpel, and the growing point examined under a binocular microscope. Inflorescence initiation was considered to have started when the growing points had widened somewhat and elongated. An average of 5 shoot apices per set were examined, and the results expressed as percentages of the growing points examined.

In field trials the onion strain Juva I (Table 1) was used. In addition to continuous cool storage (7 $^1/_2$ — 8 months at 3—5° or 9—13° C), some of the sets were given heat treatment of various durations (1 $^1/_2$ — 6 months at 28° C) following the cool storage. The onions were planted at distances of 30×25 cm in plots 3.1 m² in area; each plot contained 42 onion sets.

Inflorescence initiation

Initiation of inflorescence primordia began first in the sets kept in the 9—13° C storage chamber. Analyses made in the middle of December or about two months after the beginning of storage, showed that at this time nearly half the growing points examined showed evidence of reproductive development (Fig. 4). One month later it was found that in the most advanced primordia the spathe initial was completely formed and surrounded the swelling growing point (Fig. 5). At the following examination (10 — 17. 2. 1961) it was observed that many of the inflorescence primordia (at terminal buds and older axillary buds) had almost reached the stage shown in Fig. 6, in which a short scape had become differentiated in addition to the spathe initial. The reproductive development in the terminal buds and in the older axillary buds was clearly more advanced than in the younger axillary buds (cf. HARTSEMA

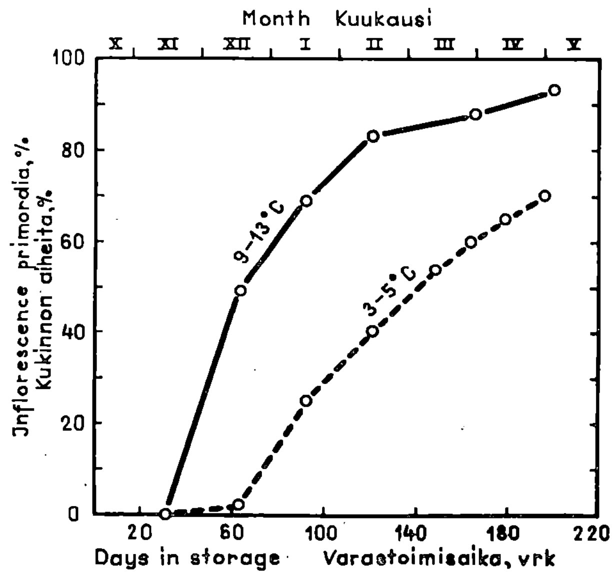

Fig. 4. Inflorescence initiation in onion sets during storage at 3—5° and 9—13° C. No inflorescence initiation occurred at the other temperatures (—1°, 21° and 31° C).

Kuva 4. Kukinnon aiheiden syntyminen varastoinnin aikana 3—5°:ssa ja 9—13° C:ssa säilytetyissä istukkaissa. Muissa varaston lämpötiloissa (—1°, 21° ja 31° C) ei kukinnon aiheita syntynyt.

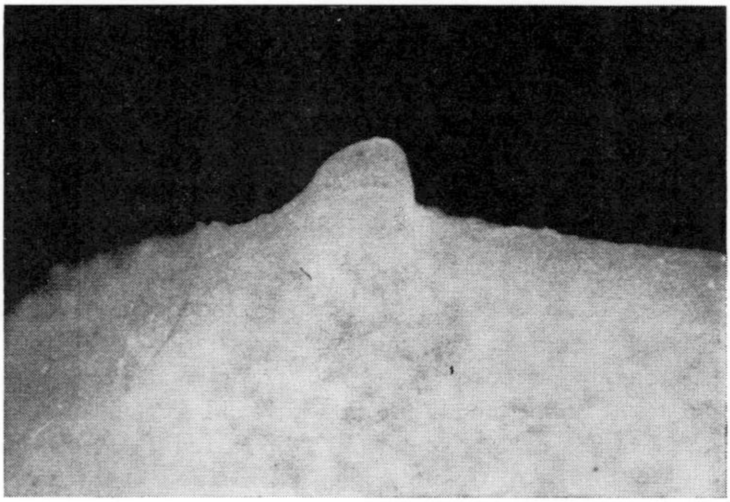

Fig. 5. Inflorescence primordium of onion at an early stage of development. The growing point has widened and elongated; it is surrounded by the open spathe intial. Adjacent to the inflorescence primordium the axillary bud initial is barely visible. Magnification about × 20.

Kuva 5. Sipulin kukinnon aihe varhaisessa kehitysasteessa. Kasvupiste on pidentynyt ja leventynyt; sitä ympäröi kukinnon suojuslehden avonainen aihe. Sen viereen on syntynyt heikosti näkyvä hankasilmun aihe. Suurennus n. 20 ×.

1947, Kazakova 1954). At the end of the storage period (6. 5. 61) inflorescence initiation had progressed very far, the longest inflorescences were 9—11 mm in length, and elongation of the scapes had already begun (Fig. 7). In the most advanced inflorescences the first individual flower initials could be distinguished.

Adjacent to every inflorescence primordium was a bud initial (Fig. 6) which had formed in the axil of the uppermost leaf initial. When the terminal bud has produced an inflorescence and thus ceased development, this axillary bud carries on the vegetative development of the plant and ultimately forms a new bulb, provided that external conditions are suitable.

As is evident from the above description, the initiation of inflorescences in onion sets occurs very early during storage in Finland (cf. Heath and Mathur 1944, Hartsema 1947). This fact may be due to varietal characteristics, to conditions during growth and ripening, or to the size of the set. The most important of these factors is perhaps the size of the set, since at the examination made on 17. 2. 1961 on small-sized sets (10—20 g) kept since 12. 10. 1960 in the 9—13° C storage chamber, it was found that in less than 50 % of the 26 growing points examined had inflorescence initiation begun. At this time the most advanced inflorescence initials in the small sets had reached the stage shown in Fig. 5. In normal-sized sets (over 40 g), on the other hand, 83 % of the growing points examined had shown initials (Fig. 4), and many of them had already reached a stage of development in which the spathe and a short

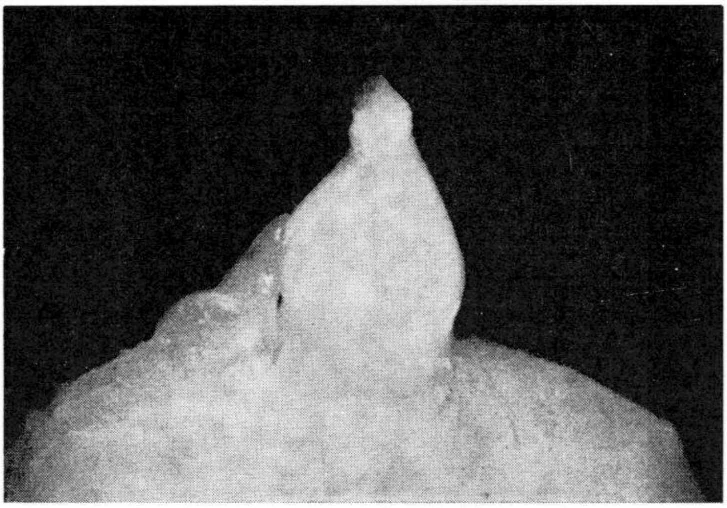

Fig. 6. Inflorescence primordium of onion. The spathe, which has already closed, has become differentiated at the end of the slightly elongated scape. The tissue within the spathe is differentiating into small meristematic regions which will give rise to the individual flowers. Adjacent to the scape is the axillary bud, whose first two leaf initials are visible. Magnification about × 20.

Kuva 6. Sipulin kukinnon aihe. Hiukan pidentyneen vanan päässä on selvästi erilaistunut kukinnon suojuslehti, joka jo on sulkeutunut. Sen sisällä oleva kasvusolukko on jakautumassa pienempiin meristemaattisiin alueisiin, joista syntyvät yksittäiset kukat. Vanan vieressä on hankasilmu, jonka 2 ensimmäistä lehtiaihetta ovat näkyvissä. Suurennus n. 20 ×.

scape had become differentiated (Fig. 6). THOMPSON and SMITH (1938) likewise found that inflorescence initiation began earlier in large sets than in small ones (cf. the hormone theory of HEATH and HOLDSWORTH 1948).

In the other storage chambers, inflorescence initiation occurred only at a temperature of 3—5° C. At this temperature initiation took place 1 $^1/_2$ — 2 months later than at 9—13° C (Fig. 4). The early stages of development of the inflorescence primordium evidently took place more slowly at the lower than at the higher temperature (cf. HARTSEMA 1947). At the end of the storage period (2. 5. 61) not even the most avdanced inflorescences had reached the stage shown in Fig. 6.

Similar investigations were also carried out on the onion strain Juva I, but no essential differences were observed between this strain and Hytti I.

The above-described results are, in the main, consistent with those obtained by BOSWELL (1924 b) on large bulbs and KAZAKOVA (1954) on vegetatively propagated Russian onions, as well as those of HEATH and MATHUR (1944) and HARTSEMA (1947) on small onion sets. WOODBURY (1950), in his investigations with large-sized bulbs of the cultivars Ebenezer and Sweet Spanish, was not able to detect the initiation of inflorescence primordia during two months'

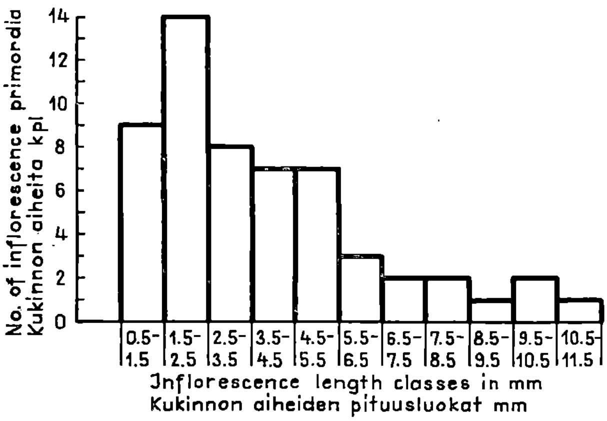

Fig. 7. Distribution of inflorescence lengths at the end of the storage period. Storage temperature 9—13° C. Length of inflorescence = length of scape + spathe.

Kuva 7. Sipulin kukinnon aiheiden lukumäärän jakautuminen pituusluokittain varastoimiskauden lopulla. Varaston lämpötila oli 9—13° C. Kukinnon aiheen pituus = vanan pituus + suojuslehden pituus.

storage. However, his trials showed that the storage temperatures (1.7°, 10.0° and 21.1° C) had an after-effect on inflorescence initiation occurring subsequently in the greenhouse; the largest numbers of primordia were initiated in the sets stored at 10.0° and the fewest in those stored at 21.1° C.

Inflorescence emergence

The emergence of inflorescences initiated during storage occurs very rapidly in Finland. In four-year trials carried out at Tikkurila (1958—61) with sets stored at 9—13° C, the time between planting and the beginning of visible inflorescence emergence ranged from a little over two weeks to one month (cf. Blaauw *et al.* 1941 a, Jones 1937). The rapid emergence of the inflorescences is apparently due to external conditions (cool spring and long day), large set size and long storage period. Because of the two latter factors, the inflorescence primordia are in an advanced stage of development at the time of planting (Fig. 7). Before the present investigations were made, it was not known to what extent inflorescences initiated during storage emerged under the conditions in this country.

In an analysis made on a field trial in 1961, it was found that in Juva I onions grown from sets stored at 9—13° C most (79 %) of the inflorescences which were initiated during the period of storage were suppressed in their emergence and destroyed (Fig. 8). The same phenomenon was also found, although to a lesser degree, in plants grown from sets stored at 3—5° C. The destruction of the inflorescences (Fig. 9) was apparently due to retardation of

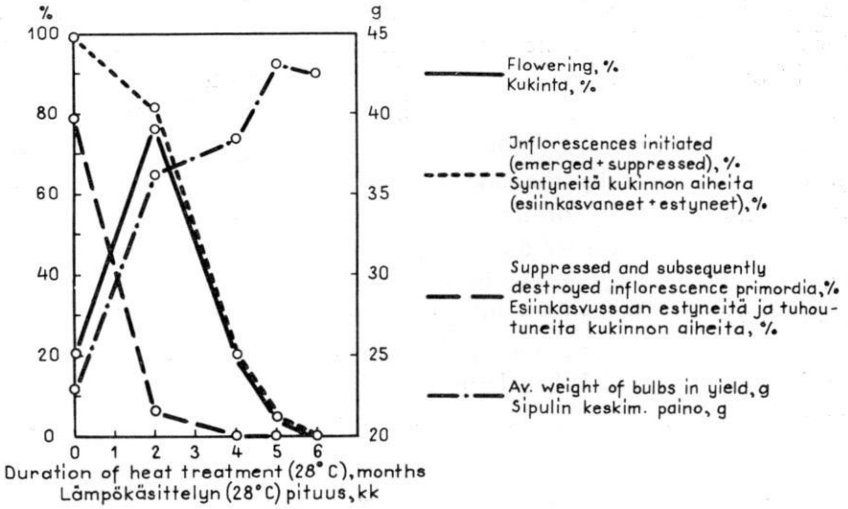

Fig. 8. Effect of duration of heat treatment on flowering and bulb weight of Juva I onions. Onions planted 16. 5., harvested and analysed 17—18. 8. Av. weight of sets 41 g, av. no. of bulbs per set 3.5. Number of plants in each treatment 42. Initial storage 9—13° C. Total length of storage period 8 months.

Kuva 8. Lämpökäsittelyn pituuden vaikutus Juva I-sipulin kukintaan ja sipulin keskimääräiseen painoon. Istutus 16. 5.; nosto ja analyysit 17—18. 8. Istukkaan keskimääräinen paino 41 g, jakautuminen keskim. 3.5 ×. Koejäsenessä 42 kasvia. Alkusäilytys 9—13° C. Säilytyskauden koko pituus 8 kk.

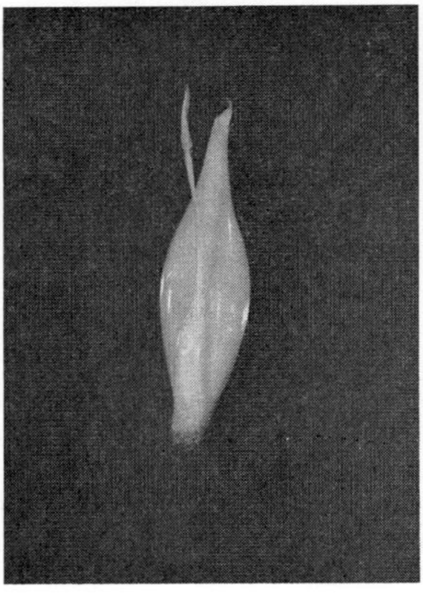

Fig. 9. Onion inflorescence primordium in an advanced stage of development but which has been destroyed. The large structure behind is a new bulb developed from the bud formed in the axil of the uppermost leaf initial. The leaf bases enclosing the destroyed primordium and the young bulb have been removed. The set had been stored at 9—13° C. Photograph taken about 5 weeks after planting. Natural size.

Kuva 9. Tuhoutunut, varsin pitkälle kehittynyt sipulin kukinnon aihe. Takana ylimmän kasvulehden aiheen hankaan syntyneestä silmusta kehittynyt uusi sipuli. Tuhoutunutta kukinnon aihetta ja sipulia ympäröivät sipulilehdet on poistettu. Istukas on ennen istutusta säilytetty 9—13° C:ssa. Kuva on otettu noin 5 viikkoa istutuksen jälkeen. Luonn. kokoa.

scape elongation resulting from rapid bulbing followed by the swelling of the leaf bases of the axillary bud adjacent to the inflorescence. Thus, the enlarging new bulb produced from the axillary bud compressed and flattened the young inflorescence against the surrounding leaf bases, which were also swelling (cf. HEATH and MATHUR 1944, HEATH and HOLDSWORTH 1948, HOLDSWORTH and HEATH 1950). Such was generally the case with the inflorescences of young axillary buds. The inflorescences of terminal buds and older axillary buds, on the other hand, developed earlier and had thickened to such an extent that they were not injured by bulbing, but in most cases emerged succesfully. The most important factor causing rapid bulbing was a low storage temperature of the sets. In plants grown from sets stored at 9—13° C bulbing began abount 4 weeks earlier than in those which had been given heat treatment either continuously or for two months (cf. Fig. 10). In the plants grown from sets stored at

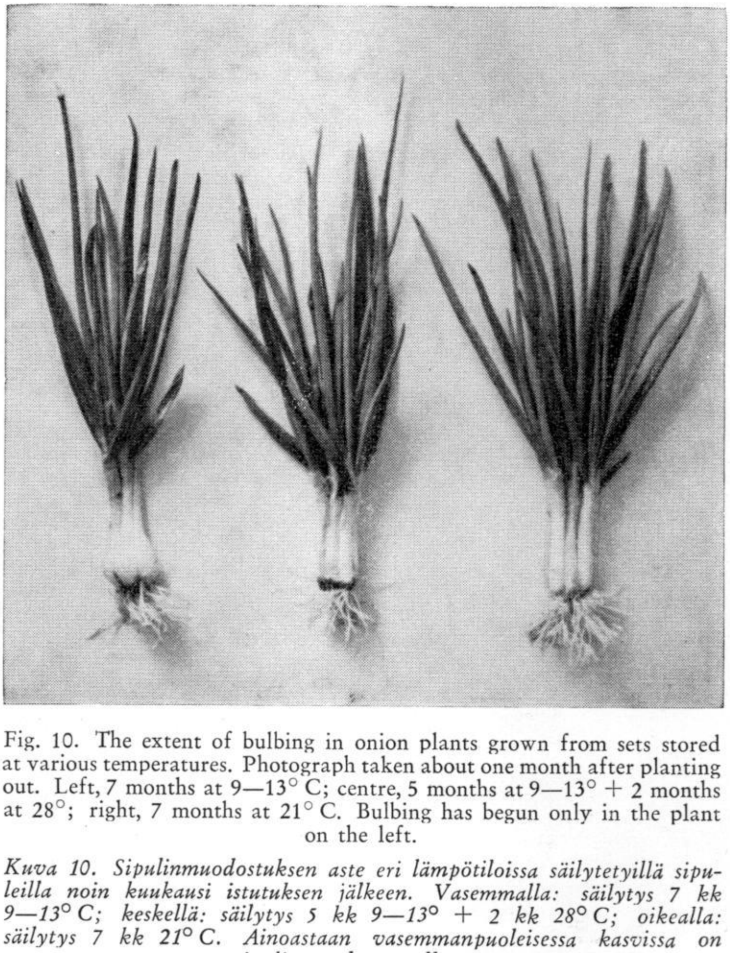

Fig. 10. The extent of bulbing in onion plants grown from sets stored at various temperatures. Photograph taken about one month after planting out. Left, 7 months at 9—13° C; centre, 5 months at 9—13° + 2 months at 28°; right, 7 months at 21° C. Bulbing has begun only in the plant on the left.

Kuva 10. Sipulinmuodostuksen aste eri lämpötiloissa säilytetyillä sipuleilla noin kuukausi istutuksen jälkeen. Vasemmalla: säilytys 7 kk 9—13° C; keskellä: säilytys 5 kk 9—13° + 2 kk 28° C; oikealla: säilytys 7 kk 21° C. Ainoastaan vasemmanpuoleisessa kasvissa on sipulinmuodostus alkanut.

3—5° C bulbing was also greatly hastened. Likewise, HEATH (1943 b), HEATH and HOLDSWORTH (1948), WARNE (1948), BRUINSMA (1957) and KNOBLAUCH (1959 b) found that heat treatment delayed bulbing.

In onion plants grown from sets that were given heat treatment (9—13° C + 2 months at 28° C), destruction of inflorescences was noted but only to a limited extent, since most of the inflorescences had emerged before the onset of bulbing. According to the analyses, only about 6.5 % of the inflorescence primordia had been destroyed in the manner described above (Fig. 8).

In examining Juva I onions of another field trial at the end of the 1961 growing season (sets stored at 9—13° C) similar results were obtained: only 35.5 % (136 out of 385) of the initiated inflorescences emerged, whereas the remainder were destroyed. After short-term heat treatment (2 months at 28° C) the corresponding percentage of emerging inflorescences was as high as 91.3 (157 out of 172).

Continuous storage of sets at low temperatures (3—13° C) may actually decrease the flowering (number of emerging flower stalks) of onions. In field trials carried out in 1960 it was found that onions grown from sets stored at a low temperature (3—5° C) were distinctly less prone to flower than those which had received heat treatment (28° C) for 1 1/2 months (p. 33, Fig. 20). Short-term heat treatment was found to increase both flowering and yield. In the following year similar results were obtained (Fig. 8). Analyses showed that the decreased amount of flowering in onions grown from sets stored continuously at low temperatures (9—13° C) was due to the suppression of inflorescence emergence (Fig. 8). The largest number of inflorescence initials occurred in the plants grown from sets stored at 9—13° C, and the number decreased as the length of heat treatment increased. This was due to the fact that the heat treatment interrupted the initiation of inflorescences during storage (cf. HARTSEMA 1947).

It was found that heat treatment delayed the emergence of inflorescences by about 4—10 days, depending on the length of the treatment. This was apparently due to the fact that development of the inflorescences stopped or was considerably retarded during the heat treatment following cool storage, and was only resumed after planting. The delay in inflorescence emergence, however, was small in comparison to the delay in bulbing.

It may be mentioned that in field trials with Hytti I onions, an increase in the duration of heat treatment (1 1/2 — 6 months) always resulted in a decreased percentage of flowering (Figs. 18, 19, 23). Destroyed inflorescences were not found after continuous cool storage. This difference in comparison with Juva I onions was probably due to varietal factors. Under greenhouse conditions cool storage led to destruction of many inflorescences in Hytti I onions as well.

HEATH and MATHUR (1944) established that high growth temperatures (averaging over 26° C) had a strong inhibitory effect — which was independent of bulbing — upon inflorescence emergence in onions grown from small sets.

This result was obtained under short-day conditions (12 $^1/_2$ hours) and thus the effect of bulbing on inflorescence emergence was eliminated.

In 1961 a trial was carried out using sets of the strain Hytti I which had been kept during their entire storage period at 9—13° C. As a result of this storage temperature, the sets had developed well-differentiated inflorescence initials at the time of planting (Fig. 7). Their average weight was 43 grams and average division 3.3.

On May 16, 1961 25 of these sets were planted in a greenhouse having a temperature of 20—29° C and continuous illumination. The presence of continuous light was presumed to accelerate scape elongation in comparison to the outdoor conditions (cf. HEATH and HOLDSWORTH 1943). Analyses made one month later on June 17 showed that only 10 % (8 out of 79) of the initiated inflorescence primordia had emerged. The rest were suppressed but not damaged. The average length of the suppressed inflorescences was 2.6 cm (0.5—7 cm). Among the corresponding plants which had been planted out in the field on May 16, over 65 % of the inflorescence initials had emerged. The suppression of inflorescence emergence in the greenhouse was thus undoubtedly a direct consequence of the high temperature. At the time of analysis, bulbing had not yet begun, so its possible effect was eliminated. It can be mentioned that slight bulb development does not prevent emergence of inflorescences (HEATH and MATHUR 1944).

Summary

The investigations were carried out with vegetatively propagated bulbs of a size (40—60 g) corresponding to that of the sets commonly used in Finland.

The most effective storage temperature for promoting the initiation of inflorescence primordia was found to be 9—13° C. At this temperature the first indications of inflorescence initiation were observed as early as mid-December, i.e. about two months after the beginning of storage. At the end of the storage period (12. 10. 1960 — 6. 5. 1961) scape elongation had already begun and the furthest developed inflorescences (scape + spathe) were more than one cm in length.

At a storage temperature of 3—5° C inflorescence initiation took place 1 $^1/_2$ — 2 months later than at 9—13° C. At the end of the storage period (12. 10. 1960 — 2. 5. 1961) practically no evidence of scape elongation was observed.

At the other storage temperatures (—1°, 21° and 31° C) no inflorescence initiation was discernible.

The inflorescences were initiated earlier in terminal and older axillary buds than in younger axillary buds. Initiation began earlier in large sets than in small ones.

In trials with onions of the strain Juva I, it was found that after cool storage (3—5° and 9—13° C) of the sets, a large number of the initiated inflorescence

primordia failed to emerge and were destroyed after the sets were planted out in the field. The suppression of emergence and the destruction of the inflorescence was principally due to the rapid bulbing caused by the cool treatment. If these same cool-stored sets were given heat treatment (1 $^1/_2$ — 2 months at 28° C) before they were planted out, flowering of the onions was increased. This was due to the fact that the heat treatment delayed bulbing by about one month, with the result that the inflorescence primordia which had been initiated during cool storage were able to emerge without hindrance.

High growth temperatures (20—29° C) were found to have a suppressing effect — which was independent of bulbing — upon the emergence of the inflorescences.

III. The formation of vegetative structures in inflorescences due to heat treatment of the sets

It is known that bulbils may occassionally develop in the inflorescences of the onion (e.g. WEBER 1929). Few reports, however, have been found in the literature concerning the factors responsible for their formation. HEATH (1943 a) found that in certain cases heat treatment (25—35° C) of sets caused the spathe to become green and elongated and that bulbils were formed within this leaf-like structure instead of flowers. The bulbils subsequently produced secondary inflorescences. According to ROBERTS and STRUCKMEYER (1952), bulbils may be formed under conditions of warmth and short light period.

In heat treatment trials of onion sets, the formation of vegetative structures in inflorescences of plants grown from treated sets was observed over a period of many years. In the 1960—61 trials, detailed observations of this phenomenon were made.

The onion strains Hytti I and Juva I (Table 1) were used in the present investigations. During the early part of the storage period (7 $^1/_2$ — 8 months) the sets were kept in storage at either 3—5° or 9—13° C. Before planting they were given heat treatment of varying intensity and duration (1 $^1/_2$ months at 21° and 31° C, or 1 $^1/_2$ — 6 months at 28° C).

Results

It was found that after treatment at 28° C and 31° C, bulbils were formed in the inflorescences of both onion strains (Figs. 11—14). In general, as the time of treatment (28° C) increased the total number of inflorescences decreased, but the proportion of inflorescences containing bulbils correspondingly increased (Figs. 11—13).

The formation of bulbils was observed only after treatment at the temperatures of 28° and 31° C (Fig. 14). Treatment at 21° C for a period of 1 $^1/_2$

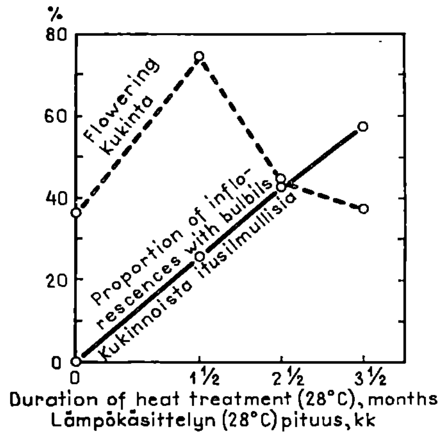

Fig. 11. Effect of duration of heat treatment on the formation of bulbils and flowering in Juva I onions, 1960. Av. weight of sets 73 g, av. no. of bulbs per set 4.4. Number of plants in each treatment 3 × 42. Initial storage 3—5° C. Total length of storage period 7 ½ months.

Kuva 11. Lämpökäsittelyn pituuden vaikutus itusilmujen syntyyn ja kukintaan Juva I-sipulilla v. 1960. Istukkaan keskim. paino 73 g, jakautuminen keskim 4.4 ×. Koejäsenessä 3 × 42 kasvia. Alkusäilytys 3—5° C. Säilytyskauden koko pituus 7 ½ kk.

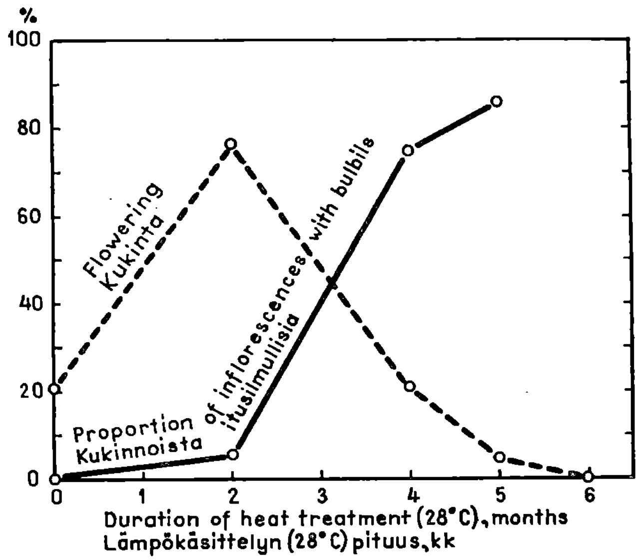

Fig. 12. Effect of duration of heat treatment on the formation of bulbils and flowering in Juva I onions, 1961. Av. weight of sets 41 g, av. no. of bulbs per set 3.5. Number of plants in each treatment 42. Initial storage at 9—13° C. Total length of storage period 8 months.

Kuva 12. Lämpökäsittelyn pituuden vaikutus itusilmujen syntyyn ja kukintaan Juva I-sipulilla v. 1961. Istukkaan keskim. paino 41 g, jakautuminen keskim. 3.5 ×. Koejäsenessä 42 kasvia. Alkusäilytys 9—13° C. Säilytyskauden koko pituus 8 kk.

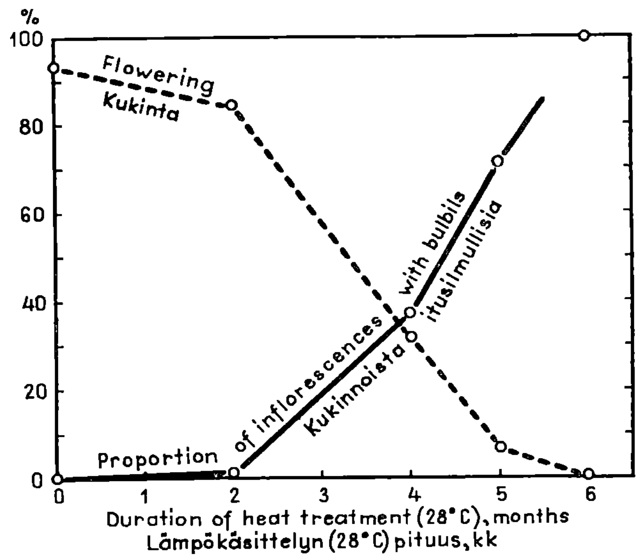

Fig. 13. Effect of duration of heat treatment on the formation of bulbils and flowering in Hytti I onions, 1961. Av. weight of sets 30 g, av. no. of bulbs per set 3.0. Number of plants in each treatment 3 × 42. Initial storage at 9—13° C. Total lenght of storage period 8 months.

Kuva 13. Lämpökäsittelyn pituuden vaikutus itusilmujen syntyyn ja kukintaan Hytti I-sipulilla v. 1961. Istukkaan keskim. paino 30 g, jakautuminen keskim. 3.0 ×. Koejäsenessä 3 × 42 kasvia. Alkusäilytys 9—13° C. Säilytyskauden koko pituus 8 kk.

months did not result in the formation of bulbils, although in many cases the spathe became green and somewhat elongated. The maximum formation of bulbils occurred after treatment at 31° C (Fig. 14).

Several different kinds of vegetative inflorescences were found to occur. A characteristic feature of all of these was the fact that the spathe elongated and turned green so as to resemble a leaf blade. Later, during the maturation of the inflorescences, these leaf-like structures split and green-shelled bulbils, varying in number from 1 to 5, were found within them. The weight of the individual bulbils varied from 0.5 to 23 g. Often normally developed flowers were also found among the bulbils. Many of the bulbils sprouted, producing leaves or secondary scapes with normal inflorescences (Fig. 15). In the secondary inflorescences, the formation of bulbils was never observed. In this respect these plants differed distinctly from the true top onion. Characteristic features of the scapes producing bulbils were their shortness as well as the fact that the enlargement was situated above the middle of the scape. The vegetative inflorescences could thus be considered to be formed on incompletely developed scapes.

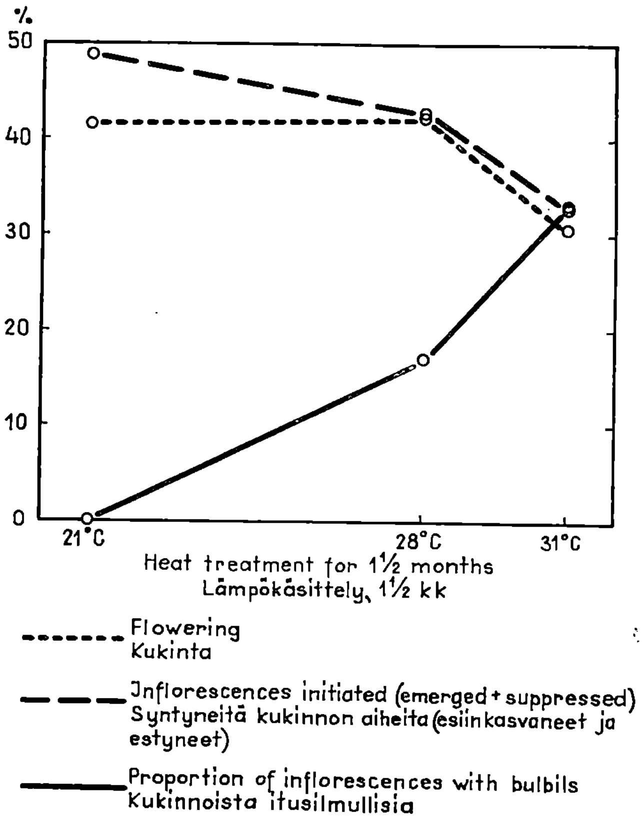

Fig. 14. Effect of temperature of heat treatment on the formation of bulbils and inflorescence primordia as well as on flowering in Juva I onions, 1961. Av. weight of sets 90 g, av. no. of bulbs per set 5.2 Number of plants in each treatment 42. Initial storage at 3—5° C for 6 ½ months.

Kuva 14. Lämpökäsittelyn lämpötilan vaikutus itusilmujen ja kukinnon aiheiden syntyyn sekä kukintaan Juva I-sipulilla v. 1961. Istukkaan keskim. paino 90 g, jakautuminen keskim. 5.2 ×. Koejäsenessä 42 kasvia. Alkusäilytys 6 ½ kk 3—5° C.

Discussion

The formation of bulbils observed in the present investigations was apparently due to storage conditions. After storage of sufficient duration and at low temperature, the apical meristems of onion sets change from the vegetative to the reproductive stage and produce inflorescence primordia (e.g. HEATH and MATHUR 1944, HARTSEMA 1947, this study, pp. 17—19). High storage temperature, on the other hand, is known to stimulate the vegetative development of onions (HEATH 1943 a, HEATH and MATHUR 1944, HARTSEMA 1947, this study pp. 19, 32—39). When sets stored at low temperature (3—13° C)

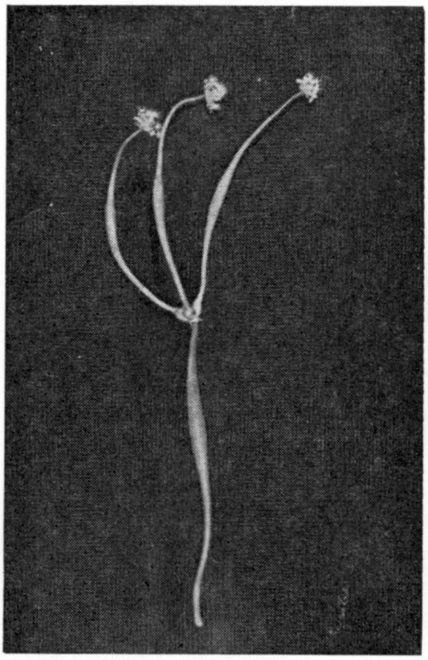

Fig. 15. Inflorescence of onion (Juva I). Three bulbils have been formed, each of which has subsequently produced a secondary inflorescence.

Kuva 15. Sipulin (Juva I) kukinto. Siihen on syntynyt 3 itusilmua, joista kustakin on kasvanut sekundäärinen kukintovana.

are transferred to a high temperature (28—31° C) it is evident that the growing points, which are just at the critical stage of onset of inflorescence initiation, may return to the vegetative state and cause the formation of leaf initials (cf. Hartsema 1947). It is probable that the higher the temperature of treatment, the more readily the growing points revert to the vegetative condition (see Fig. 14, showing the effect of various temperatures on inflorescence initiation). If, however, the inflorescence primordium has already developed to a certain extent at the start of the heat treatment, its meristem may undergo a transformation so as to produce bulbils, either partially or completely. An apical meristem in the early stages of differentiation will probably produce only one bulbil, and the scape will remain short (Fig. 16, specimen of the left). On the other hand, if the primordium is further developed at the beginning of heat treatment, it will produce a longer scape and several bulbils (Fig. 16, centre and right specimens), among which may also be completely normal flowers.

The formation of secondary inflorescences shows that in some cases the cool storage preceding heat treatment has an inductive (vernalizing) effect on secondary floral initiation.

Summary

After cool storage (3–5° and 9–13° C) of onion sets of the strains Juva I and Hytti I, heat treatment at 28° and 31° C was found to cause the formation of bulbils in the inflorescences. A temperature of 21° C for a period of 1 $^1/_2$ months,

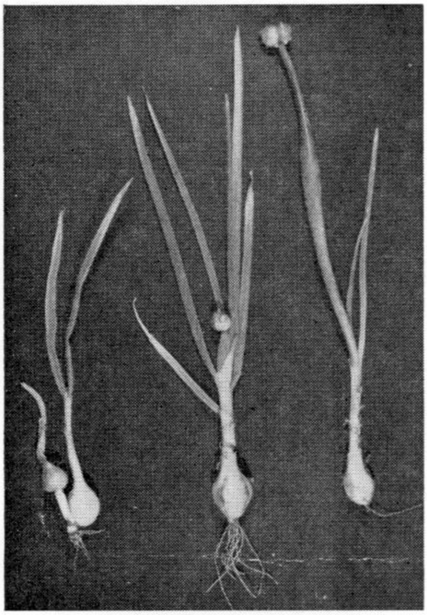

Fig. 16. Three different types of vegetative inflorescences in Juva I onions. In the specimen on the left the dry leaf bases surrounding the bulb have been removed. The true onion bulb produced from the axillary bud can be seen adjacent to the scape developed from the terminal bud and containing a single large bulbil at its tip.

Kuva 16. Kolme eri tyyppistä Juva I-sipulin "vegetatiivista" kukintoa. Vasemman puoleisesta kasvista on poistettu ympäröivät, jo osittain kuivuneet sipulilehdet. Kasvissa voidaan havaita kärkisilmusta syntyneen lyhyen, itusilmuun päättyvän vanan vieressä hankasilmusta syntynyt varsinainen sipuli.

however, resulted only in the spathe becoming green and slightly elongated. Maximum bulbil formation occurred after treatment at 31° C. In some cases the bulbils sprouted, producing either a secondary scape with a normal inflorescence or foliage leaves. Among the bulbils, normally-developed flowers often occurred.

It was concluded that, in the early stages of its differentiation, the inflorescence primordium may be induced by heat treatment to revert to the vegetative condition, producing leaf initials or bulbils. The earlier the stage of differentiation at which treatment is begun, the more complete is the reversion of the primordium to the vegatative condition. In extreme cases the growing point can, on the one hand, begin to form new leaf initials; on the other hand, it can produce an inflorescence that is almost normal but contains bulbils in addition to flowers.

IV. Flowering and yield as influenced by storage temperature

Flowering of the onion is highly dependent on the storage temperature of the sets. The finding of Boswell (1924 b) that storage at 0° C reduced flowering as compared to storage at 4.4° and 10° C initially drew the attention of research workers to the suppressing influence of low temperatures on flowering. Several years later, Jones (1928) observed that high temperatures (30° C) also had the same type of effect. On the basis of trials of many years' duration, Thompson and Smith (1938) showed that flowering of onions was most abundant after storage of the sets at 4.4° and 10° C and that it decreased as a result of both low (0° and —1.1° C) and high (15.6 — 21.1° C) storage temperatures. Although their trials indicated that storage of sets at 15.6 — 21.1° C reduced flowering somewhat more than storage at —1.1° C, nevertheless they recommended the low temperature, since high-temperature storage resulted in a large amount of spoilage of the sets.

Many other investigators (HEATH 1943 a, BLAAUW *et al.* 1944 a, HEATH *et al.* 1947, HARTSEMA 1947, LACHMAN and UPHAM 1954, LACHMAN and MICHELSON 1960) have since studied the same question and have found that the use of high temperatures is clearly more effective than low temperatures in preventing flowering in the onion. In recent years the cultivation of heat-treated sets (20 —30° C) has greatly increased in Europe. It is noteworthy that the effect of heat treatment in increasing onion yield is largely independent of its effect in preventing flowering (e.g. THOMPSON 1935, BLAAUW *et al.* 1941 b, HEATH 1943 a, HEATH *et al.* 1947, WARNE 1948, BRUINSMA 1957, KNOBLAUCH 1959, this study, pp. 34, 38).

The mode of action of storage temperature on flowering in the onion was elucidated in the 1940's. At that time both HEATH and MATHUR (1944) and HARTSEMA (1947) showed that the suppressive effect of high and low temperatures on flowering is due to prevention of inflorescence initiation during storage. In the same studies it was found that storage at 5—13° C greatly promoted the initiation of inflorescence primordia. As far as is known, high storage temperatures have never been observed to cause the destruction of inflorescence primordia; in some cases, however, growing points which have entered the reproductive phase may revert to the vegetative condition (HARTSEMA 1947, this study, pp. 28—29).

In the following experiments the aim was to determine the effect of different storage temperatures as well as various combinations of heat and cool treatments of large-sized sets (over 30 g) upon the yield and abundance of flowering (emerged flower stalks) in the onion.

Material and methods

Four Finnish onion strains were used in these trials: Hytti I, Juva I, Juva II and Lemi (Table 1). In accordance with the general practice in this country, all the sets used were vegetatively propagated.

Healthy onion sets of uniform size were selected for the trials. After being harvested, they were dried for about 3 weeks at 24—28° C before the commencement of storage. The relative humidities of the various storage chambers were as follows: 0° C and below: 73—80 %; 3—5° C: 88—94 %; 9—14° C: 45—70 %; 20—22° C: 50—60 %; 28° C: 40—50 %; 30—31° C: 33—40 %.

All the trials were outdoor field trials located on sandy soil at Tikkurila. The plots were 3.1 m² in area and the distance between sets 25×30 cm. There were thus 42 sets in each plot. The final observations on flowering were made

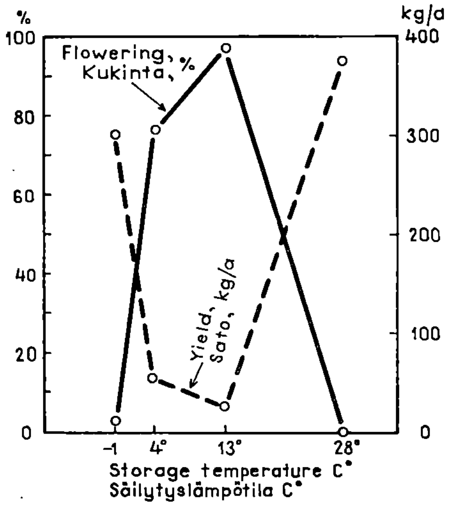

Fig. 17. Effect of storage temperature on flowering and yield in Hytti I onions, 1958. Planted out 22.5; harvest 15—16. 8. Av. weight of sets 40 g, av. no. of bulbs per set 4.0. Number of plants in each treatment 3 × 42. Total length of storage period 7 ½ months.

Kuva 17. Säilytyslämpötilan vaikutus Hytti I-sipulin kukintaan ja satoon v. 1958. Istutus 22. 5.; nosto 15—15. 8. Istukkaan keskim. paino 40 g, jakautuminen keskim. 4.0 ×. Koejäsenessä 3×42 kasvia. Säilytyskauden koko pituus 7½ kk.

at the time of lifting and topping. The percentage flowering was calculated on the basis of the number of daughter bulbs produced.

Results

Trials in 1958 and 1959. When the storage temperature of the sets was kept almost uniform during the entire storage period, flowering was most abundant after storage at 12—14° C (97 %), slighly less after 3—5° C (77 %), and very infrequent after temperatures of —2 — 0° C (3 %). With a storage temperature as high as 28° C, no flowering occurred at all (Fig. 17).

The best yields were obtained after storage at 28° and —1° C, whereas storage at 3—5° and 12—14° C resulted in a great decrease in yield (Fig. 17).

The duration of the heat treatment required to prevent flowering appeared to be dependent upon the initial storage temperature. When the latter was 3—5° C, a considerably shorter heat treatment was needed than when it was 9—14° C (Figs. 18, 19). As the duration of heat treatment increased and flowering correspondingly decreased, the yield rose steeply.

In 1959, the trials were continued with storage temperatures below 0° C. During these trials it was found that sets stored at temperatures below the freezing point gave lower yields than those which had been stored at 20—22° and 30° C (Tables 2 and 3). These results were thus similar to those obtained in the previous year (cf. Fig. 17). Flowering occurred in only one of the two trials. In both trials storage at 20—22° C proved to be better than at 30° C. Storage below 0° C was found to have other unfavourable effects in addition to lowering the yield. For instance, sprouting of the sets in the field was considerably delayed. This was caused by a lengthening of the rest period (cf. p. 56, Table 6), which also led to a delay in ripening. Furthermore, the

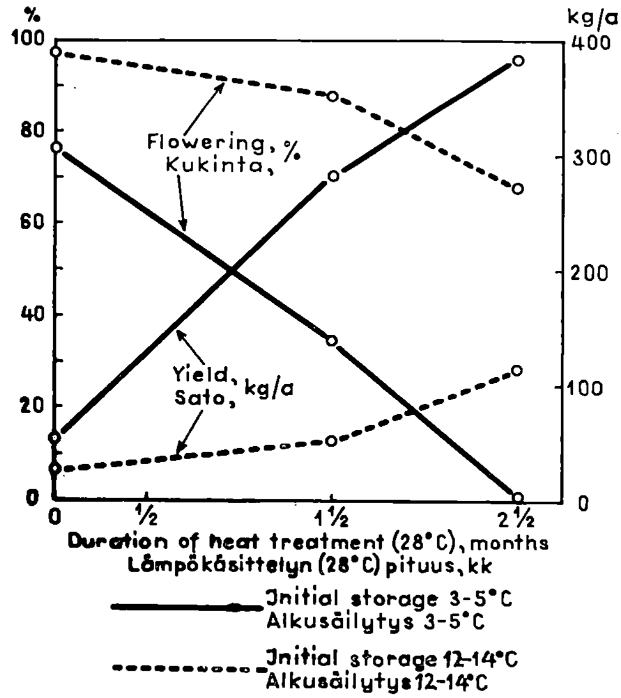

Fig. 18. Effect of initial storage temperature and length of heat treatment on flowering and yield in Hytti I onions, 1958. Planted out 22. 5.; harvest 15—16. 8. Av. weight of sets 40 g, av. no. of bulbs per set 4.0. Number of plant in each treatment 3×42. Total length of storage period 7 ½ months.

Kuva 18. Alkusäilytyksen lämpötilan ja lämpökäsittelyn pituuden vaikutus Hytti I-sipulin kukintaan ja satoon v. 1958. Istutus 22. 5.; nosto 15—16. 8. Istukkaan keskim. paino 40 g, jakautuminen keskim. 4.0 ×. Koejäsenessä 3 × 42 kasvia. Säilytyskauden koko pituus 7 ½ kk.

mortality of sets stored below 0° C was greater than that of warm-stored sets. A delay in sprouting was also noted in sets stored at 30° C as compared with those stored at 20—22° C (cf. p. 56), but no definite retardation of ripening was observed. This was apparently due to the fact that the 1959 growing season was extremely dry and warm and thus favourable for rapid bulbing and ripening.

T r i a l s i n 1 9 6 0. In 1960, heat treatment trials were continued with Juva I onions in order to establish possible differences between this strain and Hytti I, which had been used in the two previous years. The results were indeed considerably different (Fig. 20). The highest percentage of flowering was not found this time after continuous cool storage at 3—5° C, but instead after 1 $^1/_2$ months' heat treatment, and even those sets which had been given 3 $^1/_2$ months' heat treatment flowered more abundantly than the cool-stored sets.

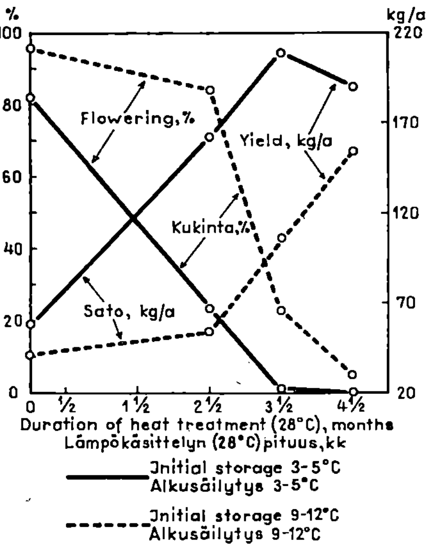

Fig. 19. Effect of initial storage temperature and length of heat treatment on flowering and yield in Hytti I onions, 1959. Planted out 22. 5.; harvest 24. 8. Av. weight of sets 37 g, av. no. of bulbs per set 3.9. Number of plants in each treatment 3 × 42. Total length of storage period 7 ½ months.

Kuva 19. Alkusäilytyksen lämpötilan ja lämpökäsittelyn pituuden vaikutus Hytti I-sipulin kukintaan ja satoon v. 1959. Istutus 22. 5.; nosto 24. 8. Istukkaan keskim. paino 37 g, jakautuminen keskim. 3.9×. Koejäsenessä 3×42 kasvia. Säilytyskauden koko pituus 7 ½ kk.

Furthermore, in 1960 trials it was found that an increase in the duration of heat treatment caused a rapid initial increase in yield. The yield increase was due to an increase in average bulb size of both flowering and non-flowering onions (Fig. 20). In these trials, as also in other later trials, division of sets was found to be somewhat dependent upon the storage temperature: heat-treated sets divided more abundantly than those which had been kept in cool storage (cf. p. 4).

Especially interesting results were obtained when heat treatment of the sets (20° and 31° C) was carried out initially before the commencement of cool

Table 2. Heat treatment trial with onion sets at Tikkurila, 1959. Planted out 29. 4.; harvest 24. 8.; 3 replicates. Onion strain: Juva I. Average weight of sets 74 g.

Taulukko 2. Istukkaiden lämpökäsittelykoe Tikkurilassa v. 1959. Istutus 29. 4.; nosto 24. 8.; kerranteita 3. Sipulikanta: Juva I; istukkaan keskim. paino 74 g.

Storage 1958/59 *Säilytys v. 1958/59*	Yield *Sato* kg/a	Flowering *Kukinta* %	Av. no. of bulbs per set *Istukkaan keskim. jakaut.*	Av. weight of bulbs produced *Sipulin keskim. paino* g
7 months *kk* 20—22° C	395.5	6.4	5.1	57.2
7 months *kk* 30° C	386.1	0.3	6.4	45.1
7 months *kk* —1 — —3° C	293.2	0.9	5.0	44.0

F-value 40.6***, least significant yield difference 35.15 kg/a
*F-arvo 40.6***, pienin merkitsevä satoero 35.15 kg/a*

Table 3. Heat treatment trial with onion sets at Tikkurila, 1959. Planted out 22. 5.; harvest 26. 8.; 4 replicates. Onion strain: Hytti I. Average weight of sets 40 g. No flowering occurred.

Taulukko 3. Istukkaiden lämpökäsittelykoe Tikkurilassa v. 1959. Istutus 22. 5.; nosto 26. 8.; kerranteita 4. Sipulikanta: Hytti I; istukkaan keskim. paino 40 g. Kukkimista ei ilmennyt.

Storage 1958/59 *Säilytys v. 1958/59*		Yield *Sato* kg/a	Av. no. of bulbs per set *Istukkaan keskim. jakaut.*	Av. weight of bulbs produced *Sipulin keskim. paino* g
7 ½ months *kk*	20—22° C	239.9	4.4	41.3
7 ½ months *kk*	30° C	201.6	4.0	38.4
7 ½ months *kk*	—1 — —3° C	165.7	4.0	31.2

F-value 18.10**, least significant yield difference 24.15 kg/a
*F-arvo 18.10**, pienin merkitsevä satoero 24.15 kg/a*

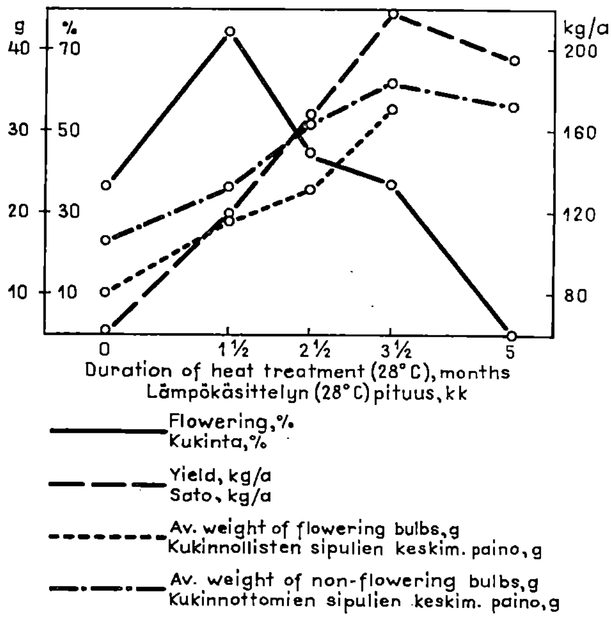

Fig. 20. Effect of length of heat treatment on flowering, yield and bulb size in Juva I onions, 1960. Planted out 19. 5.; harvest 19—20. 8. Av. weight of sets 73 g, av. no. of bulbs per set 4.4. Number of plants in each treatment 3 × 42. Initial storage at 3—5° C. Total length of storage period 7 ½ months.

Kuva 20. Lämpökäsittelyn pituuden vaikutus Juva I-sipulin kukintaan, satoon ja sipulin kokoon v. 1960. Istutus 19. 5.; nosto 19—20. 8. Istukkaan keskim. paino 73 g, jakautuminen keskim. 4.4 ×. Koejäsenessä 3 × 42 kasvia. Alkusäilytys 3—5° C. Säilytyskauden koko pituus 7 ½ kk.

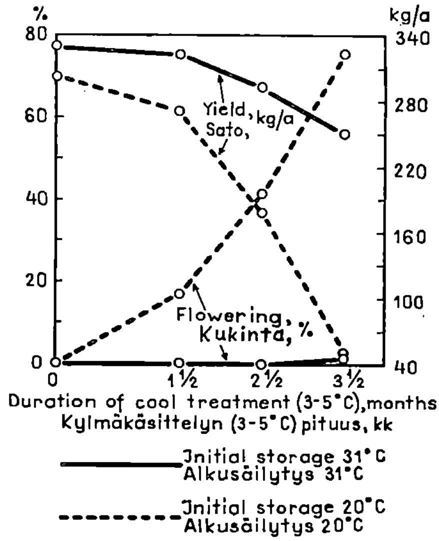

Fig. 21. Effect of initial storage temperature and length of cool treatment on flowering and yield in Juva I onions, 1960. Av. weight of sets 48 g, av. no. of bulbs per set 3.4. Number of plants in each treatment 3 × 42. Total length of storage period 7 ½ months.
F-value = 23.64***; least significant yield difference 60.88 kg/a.

*Kuva 21. Alkusäilytyksen lämpötilan ja kylmäkäsittelyn pituuden vaikutus Juva I-sipulin kukintaan ja satoon v. 1960. Istukkaan keskim. paino 48 g, jakautuminen keskim. 3.4 ×. Koejäsenessä 3×42 kasvia. Säilytyskauden koko pituus 7½ kk. F-arvo = 23.64***; pienin merkitsevä satoero 60.88 kg/a.*

storage (3—5° C). It was found that the temperature of the heat treatment had a decisive effect on flowering (Fig. 21). When the sets were initially kept at 31° C, flowering of the onions was extremely sparse (1.5 %) even after 3 1/2 months of cool storage. On the other hand, if the initial temperature was 20° C, a cool storage period lasting only 2 1/2 months resulted in profuse flowering (over 40 %).

As the duration of cool storage increased, the yield as well as the average bulb weight of both flowering and non-flowering onions decreased (Figs. 21 and 22). This decrease was smaller when the initial storage had taken place

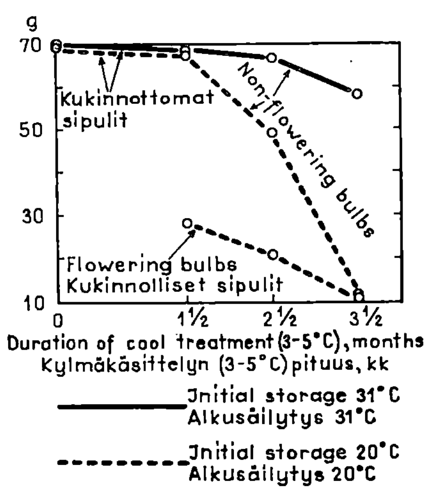

Fig. 22. Effect of initial storage temperature and length of cool treatment on bulb size, 1960. Same experimental material as in Fig. 21.

Kuva 22. Alkusäilytyksen lämpötilan ja kylmäkäsittelyn pituuden vaikutus sipulin kokoon v. 1960. Materiaali sama kuin kuvassa 21.

at 31° C. Cool storage was also found to accelerate the ripening of the onions, an effect which was in direct proportion to the duration of the cool storage. Ripening occurred more rapidly when the initial storage temperature was 20° C. No noteworthy difference in the rate of ripening was observed after continuous storage at the two high temperatures 20° and 31° C.

T r i a l s i n 1 9 6 1. In 1961, the heat treatment trials were continued with four different onion strains and with sets of different sizes. In addition, studies were made to determine whether it would be possible to replace the heat treatment given at the end of the storage period with freezing treatment.

The results of heat treatment trials with Hytti I onions were similar to those obtained earlier. When the initial storage temperature was 9—13° C, a longer heat treatment was necessary in order to prevent flowering than when the temperature had been 3—5° C (Fig. 23). Flowering was also more abundant in

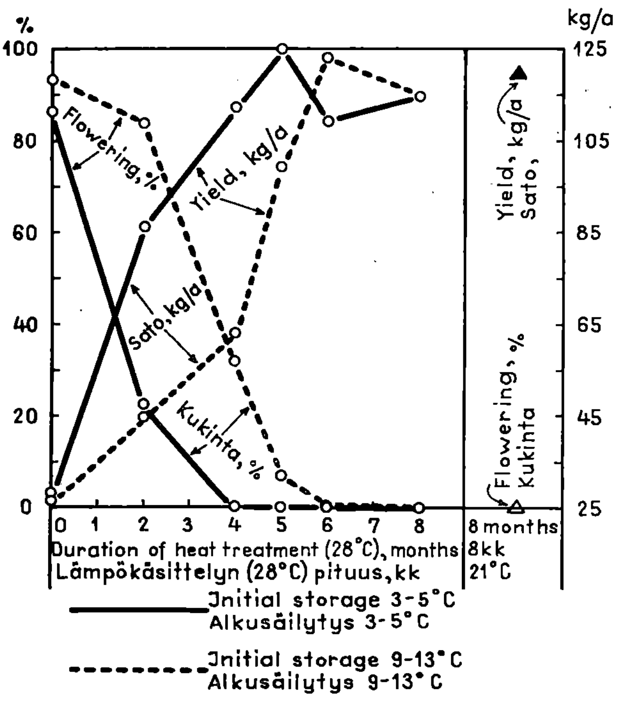

Fig. 23. Effect of initial storage temperature and length of heat treatment on flowering and yield in Hytti I onions, 1961. Planted out 16. 5.; harvest 20. 8. Av. weight of sets 30 g, av. no. of bulbs per set 3.4. Number of plants in each treatment 3 × 42. Total length of storage period 8 months.

Kuva 23. Alkusäilytyksen lämpötilan ja lämpökäsittelyn pituuden vaikutus Hytti I-sipulin kukintaan ja satoon v. 1961. Istutus 16. 5.; nosto 20. 8. Istukkaan keskim. paino 30 g, jakautuminen keskim. 3.4×. Koejäsenessä 3×42 kasvia Säilytyskauden koko pituus 8 kk.

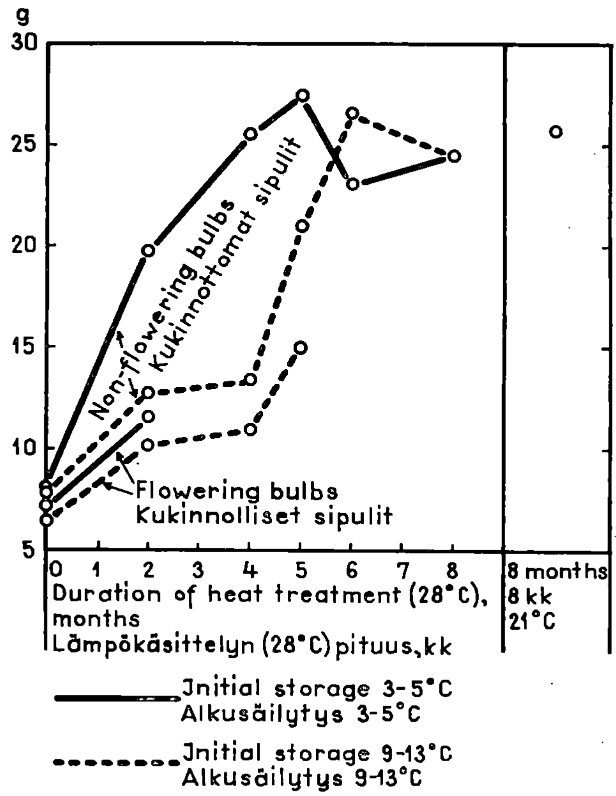

Fig. 24. Effect of initial storage temperature and length of heat treatment on bulb size, 1961. Same experimental material as in Fig. 23.

Kuva 24. Alkusäilytyksen lämpötilan ja lämpökäsittelyn pituuden vaikutus sipulin kokoon v. 1961. Materiaali sama kuin kuvassa 23.

these trials after continuous storage at 9—13° C than at 3—5° C. After storage at 21° and 28° C no flowering whatsoever occurred. The best yields were obtained when the sets had been stored at high temperatures during the entire period of storage, or when the heat treatment had been of such long duration that flowering was completely or almost completely prevented. A rise in yield was again found to be related to an increase in the weight of the bulbs (cf. Figs. 23 and 24).

After continuous storage of sets at 3—5° and 9—13° C, the plants ripened [1]) about one month earlier than if they had been given heat treatment. No clear differences in date of ripening were noticed between the various heat-treated groups.

[1]) The term "ripening" refers here, as elsewhere in this paper, only to the ripening of non-flowering onions.

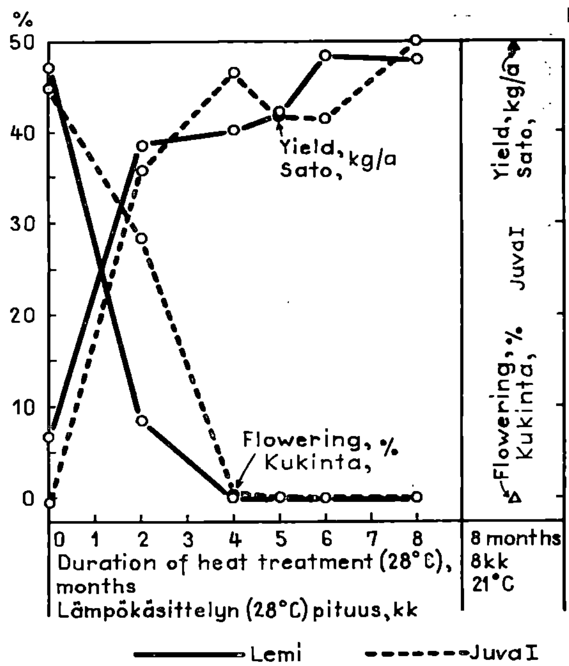

Fig. 25. Effect of length of heat treatment on flowering and yield in Juva I and Lemi onions, 1961. Planted out 16—17. 5.; harvest 17—18. 8. Av. weight of Juva I sets 41 g, of Lemi sets 62 g; av. no. of bulbs per set 3.4 in Juva I, 4.0 in Lemi. Number of plants in each treatment 2 × 42. Initial storage at 3—5° C. Total length of storage period 8 months.

Kuva 25. Lämpökäsittelyn pituuden vaikutus Juva I- ja Lemi I-sipulin kukintaan ja satoon v. 1961. Istutus 16—17. 5., nosto 17—18. 8. Istukkaan keskim. paino Juva I: 41 g, Lemi: 62 g; jakautuminen keskim. Juva I: 3.4×, Lemi: 4.0×. Koejäsenessä 2 × 42 kasvia. Alkusäilytys 3—5° C. Säilytyskauden koko pituus 8 kk.

The results of the 1961 trials with Juva I onions differed from those of the previous year in that a shorter heat treatment was sufficient to prevent flowering (Fig. 25). Another difference between the 1960 and 1961 trials was that short-term heat treatment in the latter year did not increase the amount of flowering. On the other hand, when the sets were initially stored at 9—13° C, a temperature at which inflorescence primordia are initiated much earlier than at 3—5° C, short-term heat treatment also caused a pronounced increase in flowering in the 1961 trials (Fig. 8). The effect of heat treatment on the yield and ripening of Juva I onions (Figs. 25 and 26) was generally similar to its effect on Hytti I onions.

Results with onions of the strain Lemi (Figs. 25 and 26) were approximately the same as with Juva I onions. The decrease in flowering after heat treatment of sets was more pronounced in the Lemi strain, however. This was probably

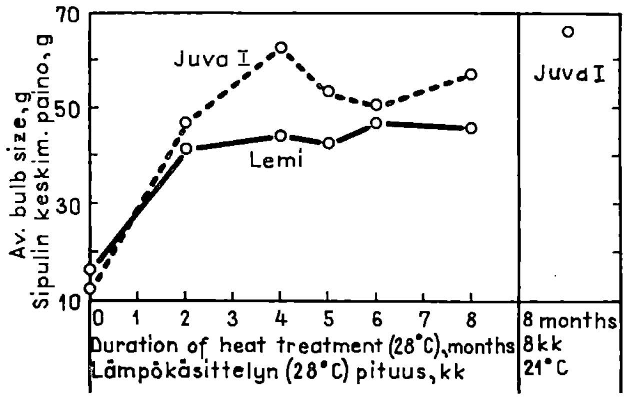

Fig. 26. Effect of length of heat treatment on bulb size, 1961. Same experimental material as in Fig. 25

Kuva 26. Lämpökäsittelyn pituuden vaikutus sipulin kokoon v. 1961. Materiaali sama kuin kuvassa 25.

due to the fact that inflorescence primordia are initiated somewhat earlier in Juva I sets.

There was found to be a relation between the size of the onion sets (strain used: Juva I) and the duration of heat treatment necessary to prevent flowering. Smaller sets required a shorter heat treatment (Fig. 27).

It had earlier been established (HARTSEMA 1947, this study, p. 19) that storage below 0° C prevents inflorescence initiation in sets during storage. In the light of this knowledge, attempts were made in the present trials to determine whether freezing treatment could replace the heat treatment given after initial storage at 3—5° C. The results proved to be partially negative (Fig. 28). It is true that the yield increased with the duration of the freezing treatment, but flowering was still abundant even after 6 months of treatment.

The disadvantageous effect of storage at —1° C was especially evident in a trial carried out with large-sized sets (Fig. 29). The low yield of onions which had been stored at —1° C was due in this case to very late sprouting (Table 6).

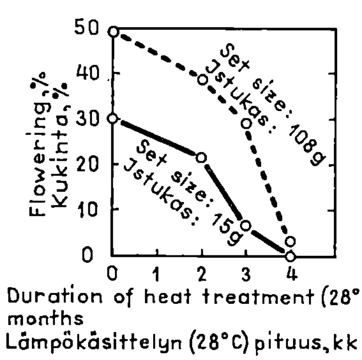

Fig. 27. Effect of set size and length of heat treatment on flowering in Juva I onions, 1961. Planted out 17. 5.; harvest 20. 8. Av. no. of bulbs produced by large sets 5.7, by small sets 1.9. Number of plants in each treatment 2×42. Initial storage at 3—5° C. Total length of storage period 8 months.

Kuva 27. Istukkaan koon ja lämpökäsittelyn pituuden vaikutus Juva I-sipulin kukintaan v. 1961. Istutus 17. 5.; nosto 20. 8. Suurten istukkaiden jakautuminen 5.7 ×, pienten 1.9 ×. Koejäsenessä 2 × 42 kasvia. Alkusäilytys 3—5° C. Säilytyskauden koko pituus 8 kk.

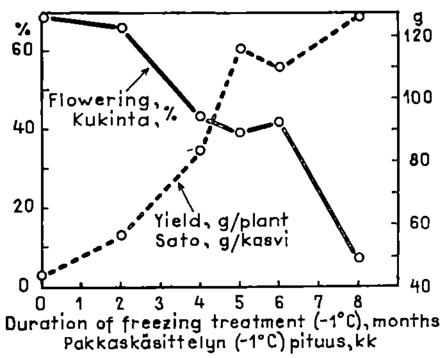

Fig. 28. Effect of length of freezing treatment on flowering and yield in Juva II onions, 1961. Planted out 7. 5.; harvest 20. 8. Av. weight of sets 58 g, av. no. of bulbs per set 2.3. Number of plants in each treatment 42. Initial storage at 3—5° C. Total length of storage period 8 months.

Kuva 28. Pakkaskäsittelyn pituuden vaikutus Juva II-sipulin kukintaan ja satoon v. 1961. Istutus 7. 5.; nosto 20. 8. Istukkaan keskim. paino 58 g; jakautuminen keskim. 2.3 ×. Koejäsenessä 42 kasvia. Alkusäilytys 3—5° C. Säilytyskauden koko pituus 8 kk.

As a result, bulbing had only just begun at the time of harvest. In this trial also, sets kept in warm storage gave the best yields, and no flowering occurred. The differences in ripening between the variously treated onions were especially evident in this trial. The most rapidly ripening plants (approx. 15.7.) were those grown from sets which had been kept in cool storage (3—5° and 9—13° C). One month later the onions stored at 21° C ripened, while those stored at 28° C still required an additional week before they were ripe. The difference in ripening dates between the last two groups of onions was at least partly due to the slower sprouting of the sets which had been stored at 28° C (cf. Table 6).

Discussion

The effect of heat and freezing treatment of onion sets in preventing flowering is a result of the suppression of inflorescence initiation during storage. Investigations made with domestic onion strains (Hytti I, Juva I) have shown that inflorescence primordia are not initiated in sets kept at temperatures of —1°, 21° and 31° C during the entire storage preriod (p. 19). As could be expected from such results, in the 1958—61 trials the onion plants which were grown from sets kept in warm storage did not flower during the growing season. There was only one exception to this finding (Table 2), and it was

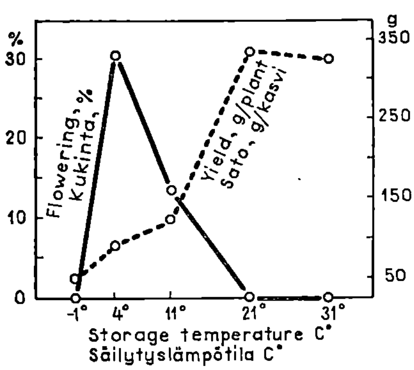

Fig. 29. Effect of storage temperature on flowering and yield in Juva I onions, 1961. Planted out 17. 5.; harvest 20. 8. Av. weight of sets 95 g, av. no. of bulbs per set 5.2. Number of plants in each treatment 42. Total length of storage period 8 months.

Kuva 29. Säilytyslämpötilan vaikutus Juva I-sipulin kukintaan ja satoon v. 1961. Istutus 17.5.; nosto 20. 8. Istukkaan keskim. paino 95 g, jakautuminen keskim. 5.2 ×. Koejäsenessä 42 kasvia. Säilytyskauden koko pituus 8 kk.

evidently due to the fact that during a cool spring and early summer inflorescence primordia were formed in the onions after they were planted out in the field (pp. 45—46). The mean temperature during the first two weeks after planting in this particular trial was only 10.0° C. There was always very little flowering after storage at temperatures below 0° C. It is obvious, however, that under field conditions inflorescence primordia are readily formed after planting out in sets which had been stored below the freezing point (cf. HARTSEMA 1947).

When cool storage (3—5° and 9—14° C) was followed by heat treatment (28° C) of varying duration, it was found that the amount of flowering decreased as the length of the heat treatment increased. One exception to this was noted (Fig. 20): the highest flowering percentage occurred in the onions that had received a short heat treatment. This was probably due to the suppression of inflorescence emergence in the sets kept in continuous cool storage (pp. 20—23). When the initial storage temperature was 9—14° C, a longer heat treatment was necessary in order to prevent flowering. This finding is in agreement with morphological studies (p. 19), which showed that inflorescence primordia were initiated much earlier during storage at temperatures of 9—13° C than at 3—5° C. The differences seen from year to year in the duration of the heat treatment needed to prevent flowering (cf. Figs. 18 and 19, as well as Figs. 20 and 25) were most likely due to the time of inflorescence initiation (cf. HARTSEMA 1947). The differences between the 1960 and 1961 trials (Figs. 20 and 25), however, were undoubtedly simply a result of the different sizes of the sets used in these years (mean weight of sets in 1960 73 g, in 1961 only 41 g). It has been established (THOMPSON and SMITH 1938, this study, p. 18) that inflorescences are initiated earlier in large-sized sets than in small ones (cf. also Fig. 27).

When heat treatment (20° and 31° C) preceded cool storage (3—5° C), the amount of flowering was principally dependent upon the initial treatment: 20° C initial storage was followed by considerably more flowering than 31° C. This was due to the fact that the higher temperature, 31° C, had an inhibitory after-effect on the initiation of inflorescence primordia during the subsequent cool storage at 3—5° C (p. 48).

When cool storage (3—5° and 9—13° C) was followed by heat treatment, the effect on the onion yield was similar in all the trials: as the duration of heat treatment increased, the yield rose correspondingly, up to a certain limit. This limit was reached earlier (i.e. after a shorter heat treatment) when the temperature of the initial storage had been 3—5° C. The effect of heat treatment in causing an increase in yield is due not only to the decrease in flowering but also to the considerably larger size of the bulbs. This latter influence appears to be principally the result of the delay in bulbing and ripening caused by heat treatment and the resultant lengthening of the growing period (HEATH 1945, HEATH *et al.* 1947). It is noteworthy that freezing treatment also produced a similar effect in delaying bulbing and ripening, with a consequent increase in yield (Fig. 28).

Heat treatment was also found to cause yield increases in those cases in which it preceded cool storage. In this instance, too, the larger yield was evidently correlated with the delay in ripening. When given at the end of the storage period, however, heat treatment had a more pronounced effect in raising the yield level. Similar results have been reported by BLAAUW *et al.* (1944 a, b), HEATH (1943 a) and WEYDAHL (1954). It is evident that the earliness of bulbing and ripening, as well as the yield, which is dependent upon these two factors, is most significantly influenced by the temperature at which the sets are kept during the last half of the storage period.

Continuous warm storage is a more advantageous method than various combinations of cool and warm treatments, at least when the initial storage is carried out at moderately high temperatures (9—14° C). In this case there is an obvious danger of flowering unless the subsequent heat treatment (28° C) is made sufficiently long, 5—6 months. If the temperature is less than 28° C, however, even longer treatment is evidently required. The size of the sets is also important in this respect, since large-sized sets require longer heat treatment or higher temperatures than small ones (cf. HEATH *et al.* 1947).

When the initial storage was carried out at low temperatures (3—5° C), a relatively short heat treatment (3 $^1/_2$ — 4 months at 28° C) was generally sufficient to prevent flowering, and the yields were practically as large as those from sets given continuous warm storage. The main disadvantage in the method using combinations of cool storage and heat treatment was the abundant sprouting occurring in the sets of certain strains (Hytti I, Juva I) when they were transferred from the cool to warm storage. KARMARKAR and JOSHI (1941) observed a similar effect. The reason for this is probably that sets whose rest phase has ended during cool storage begin to sprout when transferred to a higher temperature, which is unable to keep them dormant (thermoperiodical forcing effect of high temperatures). Most of the sets, however, generally remain dormant. If the temperature of the heat treatment is high enough (over 28° C), the sets can at least partly return to a secondary rest phase.

If sets are kept continuously in warm storage during the entire storage period, the temperature need not be so high as in the case of combinations of cool storage and heat treatment. Temperatures of 20—22° C are probably sufficient. Such temperatures, however, do not have an after-effect in preventing subsequent inflorescence initiation. This type of after-effect can be advantageous in those cases when the spring weather is unusually cool after planting (cf. p. 48) or when it is necessary to transport the sets for rather long periods of time. Sets stored at 20—22° C gave higher yields than those stored at 28—31° C, but the differences were small. Similar results were also obtained by BLAAUW *et al.* (1944 a) and HEATH *et al.* (1947).

Summary

The present investigations were carried out with four Finnish onion strains. The sets used were large-sized (over 30 g), vegetatively propagated bulbs.

When the storage temperature of the sets was kept almost constant throughout the storage period, flowering of the onions was most abundant after 9—14° C storage, somewhat less after 3—5° C, and very slight or completely lacking after storage at —3 — 0° C. With one exception, storage of sets at temperatures of 20 — 31° C resulted in no flowering at all. The best yield results were generally obtained after 20—22° C storage. In all the trials cold storage (—3 — 0° C) proved to give lower yields than warm storage (20 — 31° C), even in those cases when there was no flowering. Cool storage (3 — 5° and 9—14° C) invariably led to considerable decreases in yield.

When cool storage (3—5° or 9—14° C) was followed by heat treatment (28° C), the length of the latter treatment required to prevent flowering was dependent upon the temperature of the initial storage; when this had occurred at 9 — 14° C, 5—6 months were required, but after initial storage at 3 — 5° C, 3 $^{1}/_{2}$ — 4 months' heat treatment were generally sufficient. Large-sized sets required longer heat treatment than small ones. Heat treatment was found to increase the average bulb weight of both flowering and non-flowering onions. Sets which had been given heat treatment for periods long enough to prevent flowering, produced yields as good as those which had been kept in continuous warm storage.

When heat treatment (20° and 31° C) of varying durations (4—6 months) preceded cool storage (3—5° C), it was found that the temperature of the heat treatment had an important effect on the flowering and yield of the onions: if the initial heat treatment had been carried out at 20° C, the following cool storage resulted in considerably more flowering and a lower yield than if the initial temperature had been 31° C. Heat treatment given immediately before planting proved to be more advantageous than the same length of treatment given at the beginning of the storage period.

A trial which attempted to determine whether heat treatment following cool storage (3—5° C) could be replaced by freezing treatment, led to partially negative result.

V. Flowering in response to a cool growing season

Cool weather conditions during the growing season — and especially in its early part — have been found by many investigators to stimulate flowering in the onion (e.g. Miller 1933, Jones *et al.* 1935, Heath *et al.* 1947, Krickl 1951, Jamalainen 1952). Relatively low temperatures (10—17° C) promote both the initiation of inflorescence primordia (Heath and Holdsworth 1943, Holdsworth and Heath 1950, Woodbury 1950) and their subsequent emergence (Heath and Mathur 1944; cf. also Thompson and Smith 1938, Woodbury 1950). In Finland, practically all onion sets are stored under warm conditions (above 18—20° C) and are therefore in a vegetative state when planted out in the field (p. 19). Thus, low temperatures during the growing season affect such onion sets in both the ways mentioned above. In cool summers flowering in onions is also increased by the long day occurring in this country, since both of these factors are known to promote the elongation of the scape (Heath and Holdsworth 1943, Holdsworth and Heath 1950).

The tendency to flower varies widely among different onion cultivars and strains (e.g. Thompson and Smith 1938, Holdsworth 1945, Heath *et al.* 1947). This fact was also very evident in a trial concerning 25 onion strains carried out at Lohja in the cool summer of 1962.[1]) Twenty-four of the strains were Finnish, while one was of German origin (Gatersleben) (Table 1).

With two exceptions, all the onion strains used in these trials were kept during the entire storage period (15. 9. 1961 — 11. 5. 1962) at a temperature of 25° C at the Department of Plant Pathology, Tikkurila. The two exceptions were the strain Kuhmo, which was stored in the grower's own warm storage room, and the German strain Gatersleben. All the sets can therefore be considered to have been in the vegetative state at the time of planting. The soil type in the trial area was heavy clay.

The results of this trial showed that almost all the onion strains flowered; only three strains — Lemi, Hytti II and Parikkala — produced no inflorescences at all (Table 4). In the case of the strain Parikkala, the amount of experimental material was small.

The differences in flowering between the various onion strains were due to genetic differences in their ability to form inflorescence primordia after planting. In those strains which were non-flowering or which flowered only slightly, there were only very few signs — or none whatsoever — of inflorescences which had been suppressed in their emergence and displaced by buds formed in the uppermost leaf axil (cf. pp. 20—22). On the other hand, there were many such suppressed inflorescences in certain of the abundantly flowering strains, especially Suolahti (Table 4). This shows that considerably more inflorescences had actually been initiated in such strains than could be inferred from their flowering. It is likely that an even greater number of inflorescence primordia would have been suppressed and destroyed if the middle part of the summer had been varmer and drier and bulbing, in consequence, more rapid. Since the trial field consisted of heavy clay, this fact, too, contributed to the delay in bulbing.

Not all the inflorescence primordia which are initiated after planting and suppressed in their emergence are destroyed as a result of pressure from the growing axillary bud; some of them remain more or less undamaged within

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[1]) Av. temp. at Lohja in 1962: June 12.4° C, July 14.9° C, August 13.1° C; normal av. temp. at Helsinki in the period 1921—50: June 14.1° C, July 17.8° C, August 16.3° C.

Table 4. Flowering of various onion strains and amounts of destroyed inflorescences in a trial at Lohja in 1962.

Taulukko 4. Sipulikantojen kukkiminen ja todettujen tuhoutuneiden kukintojen määrä v. 1962 Lohjalla suoritetussa kokeessa.

Onion strain *Sipulikanta*	Flowering % calculated on the number of daughter onions produced *Kukkimisprosentti laskettuna syntyneiden tytärsipulien lukumäärästä*	% of destroyed inflorescences in non-flowering daughter onions *Kukintojen tuhoutumisprosentti kukkimattomissa tytärsipuleissa*
Suolahti	58.0 (83/143)	65.0 (13/20)
Saari II	56.7 (17/30)	0.0 (0/10)
Lavia	52.2 (12/23)	—
Pudasjärvi	51.6 (465/902)	16.3 (27/166)
Kontiolahti	47.0 (95/202)	23.1 (6/26)
Oulainen	46.3 (44/95)	28.6 (4/14)
Juva II	43.2 (149/345)	0.0 (0/43)
Kuhmo	33.9 (102/301)	3.3 (1/30)
Savitaipale II	32.8 (153/467)	11.8 (6/51)
Kuusamo	31.7 (58/183)	13.3 (4/30)
Rääkkylä II	26.5 (39/147)	25.0 (5/20)
Kitee	25.0 (22/88)	4.8 (1/21)
Rääkkylä I	13.9 (22/158)	16.7 (5/30)
Pielisjärvi I	13.9 (32/231)	0.0 (0/41)
Tuupovaara III	12.9 (40/311)	0.0 (0/26)
Saari I	8.2 (24/292)	0.0 (0/49)
Pielisjärvi II	7.8 (32/412)	3.6 (2/55)
Juva I	7.6 (21/278)	6.4 (5/78)
Pyhäselkä	7.5 (10/133)	0.0 (0/40)
Tuupovaara II	3.6 (3/84)	0.0 (0/15)
Gatersleben	1.5 (2/132)	0.0 (0/20)
Lohja	0.7 (5/731)	—
Lemi	0.0 (0/478)	0.0 (0/62)
Hytti II	0.0 (0/480)	0.0 (0/65)
Parikkala	0.0 (0/44)	0.0 (0/6)

the bulb. This probably applies especially to late-initiated primordia, whose emergence is prevented purely by the process of bulbing. These cases, however, can be considered quite rare. For example, in examining onions of the strain Oulainen grown in the 1962 trials at the Department of Plant Husbandry, Tikkurila, it was found that there were inflorescence primordia in 11 % of the non-flowering onions (83 out of 755), but in only 6 % (5 out 83) of these were non-damaged inflorescences found. The length of these latter ranged from 0.5 to 2.5 cm. It has not been determined whether such "pre-initiated" inflorescence initials are able to emerge in the following growing season regardless of the storage conditions.

Flowering caused considerable yield reductions in the trials at Lohja 1962 (cf. Aura 1958). Since the inflorescences began to emerge relatively early, shortly after the middle of July, they were able to grow very far by harvest time, thus spoiling the entire bulb. In many of the inflorescences the spathe had already opened and the scapes had reached their maximum length. When inflorescences are initiated after planting, they emerge from almost the exact centre of the onion, a fact due to the late initiation of the inflorescence and the weak development of the axillary bud. On the other hand, when inflorescences are initiated during the time of storage, the scape begins to elongate much earlier, and the vigorously-growing axillary bud forces the scape more or less to the side of the onion. In this case the new daughter bulb formed from the axillary bud can often be separated from the scape and the enclosing dry leaf bases.

In an earlier trial at the Department of Plant Pathology, Tikkurila, it was found that the onion strain Hytti I flowered especially profusely as a result of cool weather in the spring of 1957 (Aura 1958). Since the sets had been stored at 20—24° C, it can be concluded that at least the majority of the inflorescences had been initiated after planting out. When the sets were allowed to sprout under warm conditions (8—13 days, av. temp. 19° C) before planting, flowering was prevented. It was thus apparent that sprouting the sets at a high temperature had an after-effect in inhibiting inflorescence initiation.

A similar sprouting trial was later (in 1959) carried out with the onion strain Juva I. In this trial also, the beneficial effect of sprouting became evident (Table

Table 5. Pre-sprouting and heat treatment trial with onion sets at Tikkurila, 1959. The sets were sprouted in limed and fertilized peat moss. 3×42 sets in each treatment. Onion strain: Juva I. Av. weight of sets 74 g. The mean temperature during the first 2 weeks after the first batch were planted out was 10.0° C and after the second 10.8° C.

Taulukko 5. Istukkaiden idätys- ja lämpökäsittelykoe Tikkurilassa v. 1959. Idätykset suoritettu kalkitussa ja lannoitetussa turvepehkussa. Koejäsenessä 3×42 kasvia. Sipulikanta: Juva I; istukkaan keskim. paino 74 g. Istutuksen jälkeisen 2 viikon kauden keskilämpötila oli 10.0° C ensimmäisen ja 10.8° C toisen istutuksen jälkeen.

Treatment *Koejäsen*	Flowering % calculated on the number of daughter onion produced *Kukkimisprosentti laskettuna syntyneiden tytärsipuleiden lukumäärästä*
Planting date 29. 4. *Istutus 29. 4.*	
Storage 20—22° C, non-sprouted *Säilytys 20—22° C, idättämätön*	6.4
Storage 20—22° C, sprouted 2 weeks *Säilytys 20—22° C, idätys 2 viikkoa*	0.9
Storage 30° C, non-sprouted *Säilytys 30° C, idättämätön*	0.3
Storage 30° C, sprouted 2 weeks *Säilytys 30° C, idätys 2 viikkoa*	0.0
Planting date 6. 5. *Istutus 6. 5.*	
Storage 20—22° C, non-sprouted *Säilytys 20—22° C, idättämätön*	3.2
Storage 30° C, non-sprouted *Säilytys 30° C, idättämätön*	0.0

5), although the untreated plants flowered considerably less than in the 1957 trial and the inflorescences appeared one month later, at the end of July. The 1959 growing season was exceptionally warm and dry. Hence it can be inferred that the small extent of flowering in the 1959 trial was principally due to the suppression of inflorescence emergence.

Storage treatment at high temperature (30° C) has also been found to have an inhibitory after-effect on inflorescence initiation (HEATH and MATHUR 1944). In the previously described trial (Table 5) the effect of different warm storage treatments on onion flowering was also investigated. These showed that flowering was more abundant after storage at 20—22° than at 30° C. It is probable that during cool weather in the spring, more inflorescences are initiated in sets which have been stored at 20—22° C than in those stored at 30° C.

Results obtained from a cool-treatment trial performed at Tikkurila in 1960 strongly support those described above. This trial showed that flowering of onions in the field was definitely dependent upon the temperature of the varm storage (20° and 31° C) preceding the cool treatment (Fig. 21). It can be considered certain that storage at the high temperature of 31° C was very effective in preventing the initiation of inflorescences during the following cool storage. No such effect was exerted after storage at 20° C.

However, the fact remains that because of the limited duration of the after-effect of heat treatment, none of the above-described methods are completely effective in preventing the initiation of inflorescences during the growing season or subsequent flowering when cool weather continues for a long time after planting. This probably explains the profuse flowering of many onion strains in the 1962 trial at Lohja in spite of the relatively high storage temperature (25° C).

Summary

In cool growing seasons onions may often flower, even though the sets have been kept in warm storage. This depends to a great extent upon the onion strain. During the cool summer of 1962 it was found that most of the 25 strains included in the trials flowered profusely and that only three did not flower at all. The greatly varying tendency of onion strains to flower is due to genetic differences in their ability to produce inflorescence initials during the cool growing season after planting.

Only a few inflorescences were found to have been suppressed in their emergence and destroyed during the period of bulbing. The probable reason for this scarcity of suppressed inflorescences was the cool and rainy summer. Under such conditions bulbing proceeds slowly and the inflorescence primordia thus have a good chance to emerge without hindrance. Suppressed inflorescences were most frequently found in the abundantly flowering strains. In a few rare cases inflorescence primordia were found which had been suppressed in their emergence but had remained undamaged within the bulb.

Heat storage of sets (30—31° C) proved to have a distinct after-effect in preventing the subsequent initiation of inflorescences. No such effect was exerted after storage at 20—22° C. Allowing the bulbs to sprout under warm conditions before planting apparently also had a similar hindering effect on inflorescence initiation.

VI. The effect of day length on growth and development

The process of bulbing in onions has long been known to be dependent upon the length of the daily light period (GARNER and ALLARD 1923, MAGRUDER and ALLARD 1937, THOMPSON and SMITH 1938). According to MAGRUDER and ALLARD (1937), the critical day length for bulb formation varies between 12 and 16 hours in different onion cultivars. In this country it is generally assumed that in southern Finland the day length is sufficient for bulbing. It is noteworthy, however, that a longer day length is necessary for ripening than for the beginning of bulb formation (MAGRUDER and ALLARD 1937, MAGRUDER *et al.* 1941 a). Since because of climatic conditions onions are planted relatively late in Finland, the length of day at the time of bulbing is already becoming shorter. In consequence, the ripening of the onions is delayed, even though the day length necessary for initiating bulbing is evidently sufficient. If the latter part of the summer and the autumn are cool and rainy, bulbing may be so retarded that the onion does not ripen at all, but instead continues growing late into the autumn. For, in addition to day length, temperature has also been found to have an important effect on bulbing (THOMPSON and SMITH 1938, MAGRUDER *et al.* 1941 b, HEATH 1943 b, JENKINS 1954; cf. KRICKL 1943, 1951). According to HEATH (1943 b), a daily light period which at high temperatures is sufficiently long to cause bulbing, is too short for this process at lower temperatures.

Besides the above-mentioned factors, the ripening of onions in this country is greatly delayed by heat treatment of the sets. It has been shown that varm storage of onion sets retards bulbing and ripening (HEATH 1943 b, HEATH *et al.* 1947, WEYDAHL 1954, this study, pp. 22, 38) and that this delay occurs specifically in northern regions, where ripening also tends to take place slowly because of climatic conditions (HEATH *et al.* 1947). This effect, however, cannot be avoided in Finland, because — as a result of the relatively cool growing season and the use of large-sized sets — onion sets which are not heat-treated will flower abundantly and consequently give low yields (JAMALAINEN 1952, this study, p. 32).

Material and methods

Day length trials were carried out in the field at the Department of Plant Pathology at Tikkurila in the years 1960 and 1961. The trial plots were located on sandy soil. Two different onion strains were used in these trials: Hytti I

(1960 and 1961) and Juva I (1961) (Table 1). In both years comparisons were made between a normal day length (15 hours 20 minutes — 18 hours 45 min.) and a short day length of 10 hours' duration. Both warm-stored and cool-stored sets were used. In 1961, additional trials were carried out in order to determine the effect of the short day (10 hours) treatment when given to Juva I onions during the first half of the growing season (16.5 — 4.7), during the latter half (5.7 — 20.9), and throughout the growing season. Artificial shortening of the daily light period was achieved by means of shading boxes made of plywood (cross-sectional area 1.4 m^2, height 1.15 m). The shading boxes were removed from the plants at 8.30 in the morning and replaced at 18.30 in the evening. The onions were planted on May 5, 1960, and on May 16, 1961. Twenty-one sets were used for each treatment. Their average weight was 57 g (Juva I) and 41 g (Hytti I) and average number of daughter bulbs per set 5.2 (Juva I) and 4.0 (Hytti I).

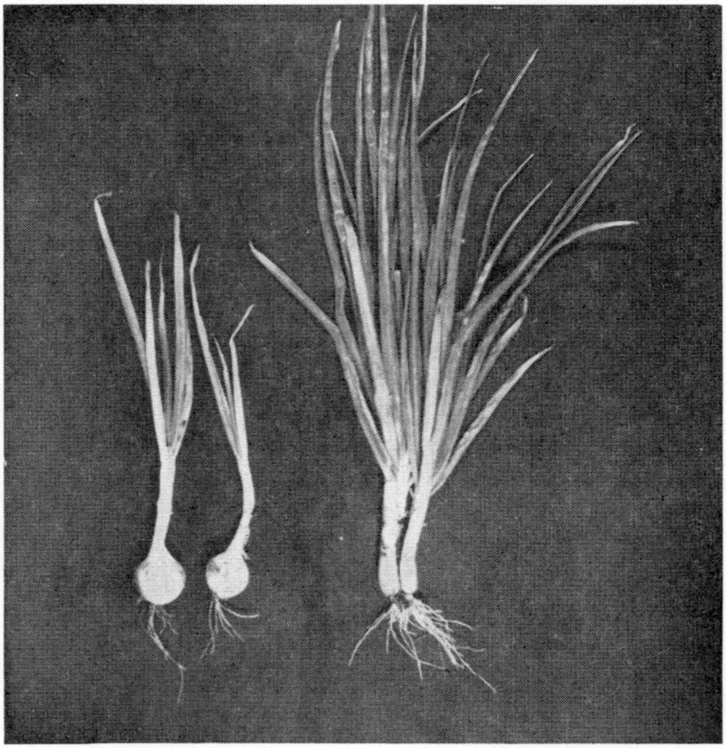

Fig. 30. The effect of day length on the growth of the onion (Hytti I). On the right, a plant grown under short-day conditions (10 hours daily); on the left, two daughter bulbs detached from a plant grown under normal-day conditions.

Kuva 30. Päivän pituuden vaikutus sipulin (Hytti I) kasvuun. Oikealla 10 tunnin päivittäisessä valojaksossa kasvanut kasvi; vasemmalla normaalissa päivän pituudessa kasvaneen kasvin 2 irronnutta tytärsipulia.

The influence of day length on vegetatively growing plants

The sets used had been stored at a temperature of 20—22° C during the entire storage period in order to prevent inflorescence initiation.

It was found in these trials that a 10-hours daily light period given during the whole growing season was not sufficiently long to cause bulb formation in either of the two strains (Fig. 30). When the trials were terminated at the end of September, the plants were still growing and no swelling of the sheathing leaf bases was visible. On the other hand, the plants growing under normal light conditions had already become sufficiently ripe to be harvested in the middle of August.

The trials carried out in 1961 showed that when onion plants (Juva I) grew for only half the growing season (either the first half or the latter half) under normal day-length conditions, bulb formation was incomplete and the plants were thick-necked. All the plants which had been given the short-day treatment during the first part of the growing season, continued their vegetative growth until the end of September, when the trials were terminated. The same response was noted in about 50 % of the plants which had grown under short-day conditions during the latter part of the season. In the remainder of these latter plants, growth stopped and their tops withered, but above the neck of the plant. The neck itself had become filled with leaves which in normal bulbing would have remained within the bulb as unswollen scales or foliage leaf initials (cf. Heath 1945, Holdsworth and Heath 1945).

Bremer (1936), who performed similar trials, found that short-day treatment (10 hours) at the beginning of the growing season (May—June) did not interfere with normal bulbing, whereas in July—August it completely prevented this process (cf. also Heath 1945, Heath and Holdsworth 1948). The results of the present investigations, which differ somewhat from those of Bremer (1936), are probably due mainly to the fact that during the critical time for bulbing the temperature was relatively low and precipitation heavy.

The onion strain Hytti I has proved to be very late under Finnish conditions. In a strain trial carried out on clay soil at Lohja in 1961 (planting date 20.5), in which 27 Finnish onion strains were tested, only about 60 % (29 out of 50 plants) of the Hytti I yield was ripe and usable; the remainder of the plants were still growing as late as the end of September. In about 20 % of the latter plants incomplete bulbing had occurred, with the sheathing bases of emerged leaves becoming enlarged. There were only 1—2 scales per bulb, if any, which were more or less unemerged, whereas in normal bulbing about 4—6 such scales are formed, the interior ones being unenlarged. Similarly in the case of Juva I onions, ripening was delayed and thick-necked plants were abundant. Almost all of the other onion strains in this trial had become ripe by the end of August. The latter part of the 1961 growing season was cool [1])

[1]) Mean temperatures at Lohja in 1961: July 16.0° C, August 14.2° C; normal mean temperatures at Helsinki, 1921—50: July 17.8° C, August 16.3° C.

and rainy, and under such conditions the effect of the shortening of day length upon ripening was evidently increased. According to MAGRUGER and ALLARD (1937), the earliness of a given onion cultivar is due to its requirements in regard to day length and also to its rate of bulbing after this minimum day length has been reached. Since the discovery that low temperatures exert a retarding influence on bulbing (THOMPSON and SMITH 1938), it has become apparent that the temperature requirements of different onion cultivars may also have a bearing on their earliness (e.g. KRICKL 1943, 1951).

The effect of day length on flowering plants

The sets (Hytti I and Juva I) had been stored at 9—13° C in order to stimulate flowering. In both years the trials showed that short-day treatment delayed and considerably retarded the emergence of the inflorescence, and as a result the scapes remained shorter than usual (Fig. 31). These results agree

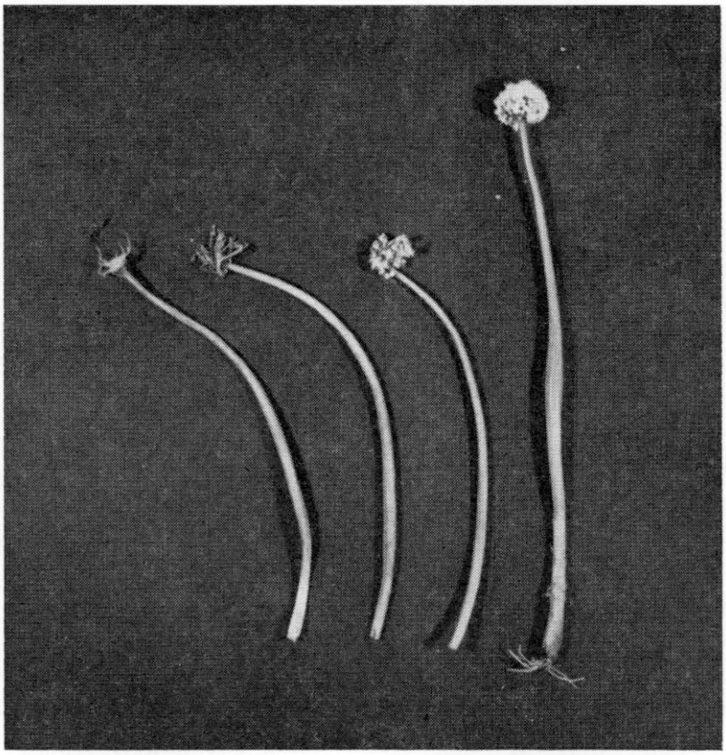

Fig. 31. The effect of day length on the inflorescence of the onion (Hytti I). On the left, three flower stalks grown under short-day conditions; on the right, a stalk grown under long-day conditions.

Kuva 31. Päivän pituuden vaikutus sipulin (Hytti I) kukintoihin. Vasemmalla kolme lyhyessä päivässä kasvanutta kukintovanaa, oikealla pitkässä päivässä kasvanut.

with those presented by THOMPSON and SMITH (1938), HEATH and HOLDSWORTH (1943), HOLDSWORTH and HEATH (1950) and WOODBURY (1950).

Short-day treatment had a definite influence on the abundance of flowering (emerged scapes) in Juva I onion plants: the percentage of emerged inflorescences in plants grown under normal light conditions was only 51.9 % (56/108), while it was as high as 88.3 % (98/111) in those plants receiving only 10 hours of light daily. This was due to the fact that under long-day conditions a large part of the inflorescence initials were destroyed as a result of the rapid bulbing caused by the low storage temperature of the sets (pp. 20—22). In Hytti I plants, on the other hand, short-day treatment caused no changes in the abundance of flowering in either of the trial years (cf. p. 23).

The length of the photoperiod was found to have other effects on flowering of the onion: when grown in a short light period, the inflorescences bore only a few flowers and the scapes often became curved, with the result that the pedicles were directed vertically upward; sometimes small sprouting bulbils were observed among the flowers (Fig. 31). This latter phenomenon has also been mentioned by ROBERTS and STRUCKMEYER (1952). In some of the flowers the tepals became slightly green and elongated.

Summary

The trials were carried out with two Finnish onion strains, Juva I and Hytti I. Plants which had been grown from warm-stored sets did not form bulbs when given short-day (10 hours) treatment. Whether the short-day treatment was given during the first half or the latter half of the growing season, bulbing was incomplete and most of the plants continued growing vegetatively until late in the autumn.

In unfavourable summers bulbing may be incomplete and the onions may not ripen as a result of the steadily decreasing day length, cool weather and raininess.

In flowering plants, the short-day treatment caused a delay in the emergence of the inflorescence. The flower stalks remained short and bore few flowers, and occasionally small, sprouting bulbils were found in them.

Short-day treatment increased the number of emerging inflorescences in Juva I onion plants. This was due to the fact that in the plants growing in a normal day length, many of the inflorescence initials formed in storage were destroyed during the process of bulbing.

VII. Rest and dormancy in bulbs at various storage temperatures

Immediately after ripening, onion bulbs are unable to produce new leaves and roots even under favourable external conditions. This period is known as the rest phase (see MANN and LEWIS 1956) and is dependent upon internal physiological factors in the bulb. According to JONES (1921) and BOSWELL (1924 a), the rest phase lasts about two months. The investigations of the former worker showed that the onion emerges from the state of rest gradually. After this period it is able to resume growth, providing that external conditions are favourable. If, however, conditions after the rest phase are not suitable for growth — owing either to natural or artificial causes, e.g. regulation of the storage conditions — the bulb does not grow but remains in a state of dormancy.

In the present investigation, studies were made on the length of the rest period in onion bulbs with respect to both sprouting and rooting under varying storage conditions. In addition, the effect of the storage temperature upon the dormancy following the rest period was investigated.

Material and methods

Two different onion strains, Hytti I and Juva I (Table 1), were used in these studies.

The onion sets were produced vegetatively. They were harvested shortly after the middle of September and were subsequently dried for three weeks at 24—28° C. Although drying is known somewhat to affect the length of the rest period (cf. LOOMIS and EVANS 1927), it was considered desirable to dry the bulbs in order that the trial conditions should correspond as closely as possible to those occurring in practice.

For the greenhouse trials healthy, uniform bulbs weighing 40—60 g were chosen. After drying, they were placed in various storage chambers having the following conditions:

temperature C°	rel. humilidy %
—1	73 — 75
3 — 5	92 — 94
9 — 13	45 — 60
21	50 — 60
31	33 — 37

The temperature in the cold storage chamber (—1° C) was approximately the freezing point of onion bulbs (cf. WRIGHT 1937).

In order to study the length of the rest period with respect to sprouting, ten bulbs from each storage chamber were taken monthly and planted in flats containing damp soil. The flats were kept in a greenhouse having a daily temperature range from 13 to 22° C. The mean daily temperature of the greenhouse was not determined, but it rises during the latter part of the winter and the spring as a result of the increased daylight. The first bulb planting was made on 12. 11. 1960 and the last on 12. 5. 1961. A bulb was considered to have sprouted when the tip of a leaf first appeared. The level of rest was expressed, in the manner of MANN and LEWIS (1956), as the period of time between planting and sprouting. Thus, the slower a bulb sprouted after planting, the deeper was its state of rest at the end of the storage period.

In studying the length of the rest period with respect to rooting, the same method was used with the exception that the bulbs were planted in damp, limed peat moss (pH 6.0—6.5) in order that the roots should not be damaged during the daily inspections. A bulb was considered to have rooted when one of the roots had reached a length of 5 mm. The time from planting to rooting was used as a measure of the level of rest. Observations on sprouting were also made on the peat moss plantings.

In addition, the rate of sprouting of onion sets (Hytti I, Juva I) kept at different temperatures was tested in field trials. In these trials the bulbs were planted in sandy soil at distances of 30×25 cm in plots 3.1 m^2 in area.

In storage trials carried out in the years 1958—61 observations were made on the sprouting of onion bulbs (Hytti I) during a storage period of about 8 months. The trial temperatures in the years 1958/59 were 9—12° and 20—22° C, in the year 1959/60 3—5°, 9—13°, 20° and 31° C, and in the year 1960/61 —1°, 3—5°, 9—13°, 21° and 28° C. The numbers of bulbs at each temperature in these years were about 2500, 650 and 200 respectively.

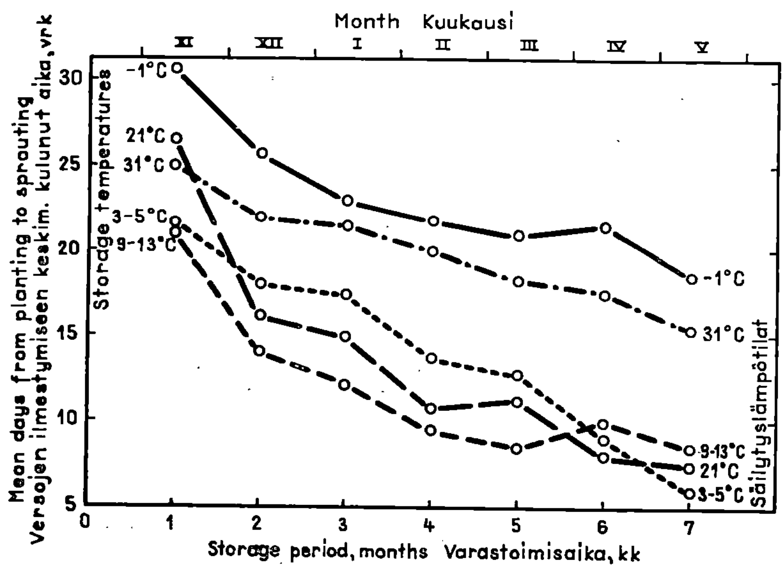

Fig. 32. The effect of storage temperature on the rate of onion bulb sprouting after varying lengths of storage. Growth medium soil.

Kuva 32. Säilytyslämpötilojen vaikutus sipulin versomisnopeuteen eri pituisten varastoimisaikojen jälkeen. Kasvualustana multa.

G r e e n h o u s e t r i a l s. In the trials carried out in soil, the onion bulbs were found to emerge most rapidly from the state of rest at storage temperatures of 3—5°, 9—13° and 21° C and most slowly at —1° and 31° C (Fig. 32). The length of the storage period also had an effect: the bulbs sprouted more rapidly after longer periods in storage. These results agree in general with those obtained by ABDALLA (1962), whose work come to the attention of the writer as late as October 1963. The increased rate of sprouting toward the latter part of the storage period was partly due to the fact that leaf initials had already begun to elongate during storage. This applies especially at the temperature of 9—13° C but also to those onions stored at 3—5° and 21° C. The rapidity of sprouting was also increased by the slight rise in temperature in the greenhouse occurring in the spring. When the trial was terminated (13. 5. 1961), only the bulbs stored at —1° and 31° C were considered to be still in the resting state; this state was deeper at the former temperature. At temperatures of 3—5°, 9—13° and 21° C the rest phase was already completed during the first half of the storage period. Storage at 9—13° C was found to be particularly effective in causing the disappearance of rest.

Similar observations made on onions planted in peat moss showed results which did not differ essentially from those in soil.

In the storage trials it was found that a temperature of 9—13° C most effectively prevented the continuation of dormancy after the end of the rest period (Fig. 33). At this temperature the onions sprouted profusely even in the first half of the storage period. Onions kept at 3—5° and 20—22° C remained much longer in a state of dormancy. At temperatures of —1°, 28° and 31° C the dormant period apparently continued uninterrupted during the entire period of storage; no sprouting whatsoever occurred in the onions stored at these temperatures. The lack of sprouting in this case may have been due to a lengthening of the rest phase.

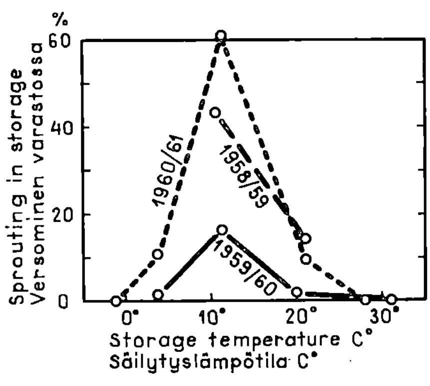

Fig. 33. The effect of storage temperature on the sprouting of onion bulbs in storage in the years 1958—60. Length of storage period 8 months. The graphs are derived from table 8, p. 61.

Kuva 33. Säilytyslämpötilojen vaikutus sipulin versomiseen varastossa vuosina 1958—60. Säilytyskauden pituus 8 kk. Kuva johdettu taulukosta 8 sivulla 61.

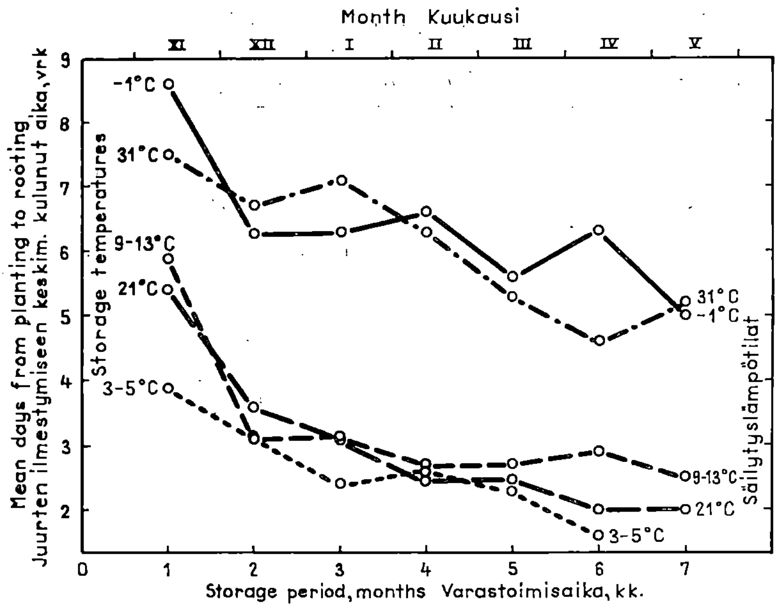

Fig. 34. The effect of storage temperature on the rate of onion bulb rooting after varying lengths of storage. Growth medium limed peat moss.

Kuva 34. Säilytyslämpötilojen vaikutus sipulin juurtumisnopeuteen eri pituisten varastoimisaikojen jälkeen. Kasvualustana kalkittu turvepehku.

Rooting of bulbs occurred most rapidly after storage at temperatures of 3—5°, 9—13° and 21° C; in general, the bulbs rooted more rapidly after longer periods in storage (Fig. 34). Thus, the weak resting state of onion roots disappeared in the same way as in sprouting (compare Figs. 32 and 34). However, roots developed in the plants much sooner than leaves. Almost all the bulbs stored at 3—5° C had already produced roots at the end of the storage period. This was due to the high relative humidity present at this temperature. At the other storage temperatures, no roots appeared during storage in any of the trial years (cf. p. 62). The humidity of the storage room thus has an important effect on the root dormancy of onion bulbs.

F i e l d t r i a l s. The field trials showed — as did also the greenhouse trials — that the bulbs which had been stored at the lowest temperature (—1° C) sprouted most slowly (Table 6). The large-sized bulbs (95 g) appeared to have been hindered most by the freezing temperature: 41 days after planting only 10 % of these bulbs had produced leaves (by the end of the growing season 37 bulbs out of 42, or 88 %, had sprouted). High temperatures (28—30° C) also delayed sprouting. This observation is in agreement with those of Carlsson (1961) and Smith (1961), who likewise reported that heat treatment retarded the sprouting of onions.

The rapid disappearance of rest at a temperature of 9—13° C became evident in the field trials when the bulbs had been stored at 28° C

Table 6. Sprouting of onion sets in field trials at Tikkurila, 1959 and 1961. Planted: 22. 5. 1959; 17. 5. 1961. No. of sets in each treatment: 42—126.

Taulukko 6. Sipulin versominen kentällä Tikkurilassa vv. 1959 ja 1961. Istutus v. 1959 22. 5. ja v. 1961 17. 5. Koejäsenessä 42—126 sipulia.

Year *Vuosi*	Onion strain and set size *Sipulikanta ja istukkaaan koko*	Storage ($7^1/_2$—8 months) at *Säilytys ($7^1/_2$—8 kk)*	Percentage of sets sprouted, days after planting *Sipulien versomisprosentti, vuorokausia istutuksesta*					
			12	13	14	16	26	41
1959	Hytti I (40 g)	—1 — —3° C	—	0.0	—	—	38.6	—
		3 — 5° C	—	88.0	—	—	—	—
		9 — 13° C	—	86.9	—	—	—	—
		20 — 22° C	—	83.3	—	—	—	—
		30° C	—	8.7	—	—	—	—
1961	Hytti I (30 g)	—1° C	0.0	—	0.0	—	73.8	—
		3 — 5° C	95.9	—	100.0	—	—	—
		9 — 13° C	95.2	—	100.0	—	—	—
		21° C	73.4	—	97.4	—	100.0	—
		28° C	47.6	—	85.4	—	100.0	—
1961	Juva I (95 g)	—1° C	0.0	—	0.0	0.0	0.0	10.0
		3 — 5° C	81.0	—	92.9	100.0	—	—
		9 — 13° C	85.3	—	94.7	100.0	—	—
		21° C	0.0	—	53.8	100.0	—	—
		28° C	0.0	—	0.0	26.2	—	—

before cool treatment. At this high temperature the rest period is apparently prolonged. Onions kept at 9—13° C after storage at 28° C sprouted much more rapidly than those kept at the lower temperature of 3—5° C after the same initial storage (Table 7).

Discussion

The trials showed that the resting phase in onion bulbs gradually changes to a state of dormancy; no sudden changes occur during the gradual disappearance of the rest state. During the time of deepest rest, the activity of the growing point is at a minimum. The investigations of ABDALLA (1962) indicate that even at this time the cells of apical meristems show evidence of mitosis

Table 7. Sprouting of onion sets in field trials at Tikkurila, 1961. Planted out 17. 5. No. of sets in each treatment: 84. Onion strain: Juva I. Average weight of sets 50 g.

Taulukko 7. Sipulin versominen kentällä Tikkurilassa v. 1961. Istutus 17. 5. Koejäsenessä 84 sipulia. Sipulikanta: Juva I; istukkaan keskim. paino 50 g.

Storage temperatures during winter 1960/61 *Säilytys v. 1960/61*	Percentage of sets sprouted, days after planting *Sipulin versomisprosentti, vuorokausia istutuksesta*	
	12	14
3 ½ months 28° C + 3 ½ months 3—5° C *kk 28° C + 3 ½ kk 3—5° C*	11.3	38.7
3 ½ months 28° C + 3 ½ months 9—13° C *kk 28° C + 3 ½ kk 9—13° C*	82.1	96.4

(cf. Stoll and Klinkowski 1951). Heath and Mathur (1944) found that in small onion sets stored at an average temperature of 12.5° C about 1—2 leaf initials were formed between mid-October and mid-March, principally during the latter part of this period (cf. Hartsema 1947). Abdalla (1962) stated that leaf initiation in mature onion bulbs had resumed already by the time the bulbs were placed in storage; this initiation was favoured by intermediate temperatures (15° C). Inflorescence primordia are normally only formed after this process (cf. pp. 45—46).

A slight elongation of leaf initials apparently begins very early during storage, especially at temperatures near the range of 13—15° C (Hartsema 1947, Abdalla 1962). After the complete termination of the rest period, the leaf initials are ready to elongate more rapidly. Most of the unswollen leaf initials which are present in onion bulbs already at the time of harvest later produce foliage leaves under suitable growing conditions (Boswell 1924 a, Hoffman 1933, Heath and Mathur 1944, Hartsema 1947). Thus, the temperatures affecting elongation of leaf initials have had an influence on the results presented here. However, the influence of temperature on leaf elongation during storage at constant temperatures is apparently similar to, but probably separete from, its effect on the initiation of leaf elongation and the formation of new leaf initials.

Storage of onion bulbs at temperatures near the range of 9—13° C appears to have a critical effect on the development of the onions in many respects. In the first place, the rest period is at its shortest at these temperatures; in the second place, inflorescence initials are formed earliest and are most numerous (Hartsema 1947, this study, Fig. 4); and in the third place, bulbing is hastened.

Summary

The present studies included greenhouse, field and storage trials with two domestic strains of onions.

The state of rest in the onion bulbs with respect to both sprouting and rooting disappeared most rapidly at storage temperatures of 9—13°, 3—5° and 21° C and most slowly at —1° and 31° C. At temperatures of 9—13°, 3—5° and 21° C the rest phase was completed during the first half of the storage period (7 months). Bulbs kept at —1° and 31° C were still in a weak state of rest at the end of storage.

Sprouting dormancy following the rest phase terminated most rapidly at 9—13° C. Rooting dormancy, on the other hand, was apparently not affected by temperature during a period of 8 months but was appreciably influenced by the humidity during storage.

VIII. Storage of commercial bulbs

The poor keeping quality of onions in storage has been one of the most serious drawbacks to onion cultivation in Finland. It is mainly for this reason that the cultivation of onions in the northern parts of the country has considerably declined (JAMALAINEN 1952).

Since the year 1947 investigations have been made at the Department of Plant Pathology on the reasons for the inferior keeping quality of onions. Results of these studies have been previously published by JAMALAINEN (1952) and SALOKANGAS (1956). Losses due to rotting in storage were very high in these trials. For example, during the storage period 1950/51, when onion lots from 38 different locations in Finland were kept in warm storage (22° C) at Tikkurila, storage losses ranged from 13.9 % to 90.5 % and averaged 61.7 % (JAMALAINEN 1952). Numerous reports about the poor keeping of onions have also been received from individual growers and commercial firms. The storage losses have been principally due to decay caused by grey mould neck rot (*Botrytis allii* Munn) and by bacteria (JAMALAINEN 1952, SALOKANGAS 1956). Sprouting during storage has also proved to be troublesome, especially in the case of onions grown from seed (SALOKANGAS 1956).

The keeping quality of onions under different storage conditions

Storage trials were carried out at the Department of Plant Pathology, Tikkurila, in the years 1958—61; in addition, some of the 1960/61 trials were also made in the onion storeroom of the commercial firm Kesko Oy at Lohja.

Onion bulbs of uniform size were selected for the trials and stored in shallow wooden crates holding about 13 kg onions. During the storage period, inspections of the trials were made at monthly intervals, at which time the sprouted and decayed onions were weighed and removed. The length of the storage period was about 8 months (from the end of September to the end of May).

The trials showed that the sprouting losses were greatest at temperatures of 9—13° C and were smaller at both lower and higher storage temperatures (Table 8, Fig. 33). These results agree with those of numerous other investigations, which indicate that onion bulbs sprout most readily at temperatures of 6—20° C (BOSWELL 1924 b, JONES 1928, WRIGHT *et al.* 1932, CLEAVER 1934, THOMPSON 1935, WRIGHT *et al.* 1935, ZELLER 1939, KARMARKAR and JOSHI 1941, BLAAUW *et al.* 1941 a, YAMAGUCHI *et al.* 1957). JONES (1928) was the first to establish that high temperatures (30° C) also prevented sprouting.

There are great differences between different onion strains in regard to their tendency to sprout. The strain Juva I, for example, sprouted much less than the strain Hytti I. Also, differences may appear in the same strain from year to year. As an example, sprouting of Hytti I onions at 9—13° C was considerably less during the storage period 1959/60 than in the previous or following year. This was probably due to the fact that the 1959 growing season was especially warm and dry, with the result that the late strain Hytti I was able to ripen early. In the other two trial years, however, this onion did

Table 8. Summarized table of onion storage trials at Tikkurila, 1958—61. Before storage the onions were dried at 25—28° C for 2—3 weeks.

Taulukko 8. Yhdistelmä sipulin varastoimiskokeista vuosina 1958—61 Tikkurilassa. Ennen varastointia sipulit kuivattiin 2—3 viikkoa 25—28° C lämpötilassa.

Storage temperature *Varaston lämpötila* C°	Rel. humidity during storage *Varaston suht. kost.* %	Storage period *Varastoimiskausi*	Onion strain *Sipulikanta*	Onions stored *Varastoitu* no. *kpl*	wt. *kg*	Sprouting losses *Versomistappio* % no. *kpl-%*	Decay losses *Mädäntymistappio* % no. *kpl-%*	Total losses *Kokonaistappio* % no. *kpl-%*	% weight *paino-%*
9—12	35—40	1958/59	Hytti I	2557	165.8	43.5	17.9	61.4	74.3
20—22	35—40	—»—	—»—	2549	169.1	4.4	28.6	33.0	50.0
3—5	88—94	1959/60	—»—	650	26.1	1.4	12.3	13.7	16.0
9—13	35—40	—»—	—»—	650	26.7	16.6	13.4	30.0	38.7
20	35—40	—»—	—»—	650	27.3	1.8	24.2	26.0	39.2
20	35—40	—»—	Juva I	600	27.8	3.2	17.8	21.0	37.4
31	25	—»—	Hytti I	650	26.3	0.0	18.8	18.8	35.0
—1	73—75	1960/61	—»—	200	9.3	0.0	20.5	20.5	21.6
3—5	92—94	—»—	—»—	200	6.3	10.0	24.5	34.5	45.6
9—13	45—60	—»—	—»—	200	6.3	61.0	8.5	69.5	76.1
21	50—60	—»—	—»—	200	6.3	9.5	21.0	30.5	46.7
28	38—43	—»—	—»—	200	6.6	0.0	8.0	8.0	29.7
—1	73—75	—»—	Juva I	300	39.1	0.0	11.0	11.0	14.3
3—5	92—94	—»—	—»—	300	38.4	0.0	9.3	9.3	14.8
9—13	45—60	—»—	—»—	300	40.0	4.7	6.0	10.7	22.7
21	50—60	—»—	—»—	300	37.0	2.3	11.0	13.3	28.9
28	38—43	—»—	—»—	300	37.6	0.0	23.3	23.3	40.4
3—5	(65–93, av. 81)	—»—	Lemi	308	33.8	0.0	39.6	39.6	45.7
3—5	92—94	—»—	—»—	308	34.1	0.0	49.0	49.0	55.3

not become completely ripe because of less favourable weather conditions. It is a well-known fact that onions which ripen late or which fail to ripen completely sprout earlier than usual during storage (Boswell 1924 b, Bremer 1937, Magruder *et al.* 1941 b, Krickl 1943, Aura 1958).

The humidity of the storage room appears not to have a great effect on sprouting. This can be concluded from the observation that the 9—13° C storage chamber, in which sprouting of the onions was most abundant, was quite dry in all the trial years; its relative humidity was only 35—60 %. On the other hand, sprouting in the damp 3—5° C storage chamber (rel. humidity 88—94 %) was without exception very slight. Similar results has also been reported by Wright *et al.* (1932, 1935).

The time when sprouting began in storage (9—13° C) varied relatively little in the different years. In general, the onions began to sprout during January; in winter 1960/61 this process started as early as the end of December.

Storage losses due to rotting were principally due to damage caused by neck rot (*Botrytis allii* Munn). The temperature of the different storage chambers had practically no influence on the rotting of the onions (Table 8). This was also found by Wright *et al.* (1932, 1935); the highest temperature in their trials, however, was only 10° C. The lack of a close correlation between decay and the storage temperature is understandable, since *Botrytis allii* is able to grow over a wide range of temperatures (3—33° C), its optimum being 20—25° C (Walker 1926; cf. Munn 1917). Further, this fungus is a wound fungus which generally infects the onion plant already on the field by penetrating into it through the neck during the period of ripening, either when the tops fall over and begin to decay or when the onions are topped (Walker and Lindegren 1924, Walker *et al.* 1925. Walker 1925, 1926, Hellmers 1943, Hatfield *et al.* 1948, Røed 1950, van Doorn 1955). Infection can even take place without the plant being damaged (Holdsworth and Heath 1945), provided the blade of the last foliage leaf has completely emerged. When this happens, the opening at the junction between the blade and the base of the leaf remains open, and the fungus is consequently able to pass through this opening directly into the succulent interior onion scales. There is apparently little spread of infection from one onion to another during the period of storage (Munn 1917). In those onions which had been infected, the decay process had already started before storage began, even though no visible external evidence could then be seen. None of the temperatures used in these trials (Table 8) were able to check the rotting process in the onions completely, although it occurred very slowly at the lowest temperatures, especially at —1° C (cf. Munn 1917, Walker 1926). In the storage chamber kept at a temperature below freezing, badly decayed onions were never found, whereas in the 20—31° C storage chambers many completely rotten onions were found.

The effect of the moisture content of the air in the storage chambers upon rotting was investigated in the storage period 1960/61. In this trial, onions of the strain Lemi were kept at a temperature of 3—5° C. Losses due to rotting were found to be about 10 per cent units smaller at the lower humidity (rel. humidity 65—93 %, average 81 %) than at the higher (92—94 %) (Table 8). According to Platenius *et al.* (1934), the humidity of the storage chamber has an appreciable effect on the keeping quality of onions when the temperature is above 0° C, but at temperatures below the freezing point the moisture content is of little importance.

The results obtained with the strain Lemi cannot be compared with those from the strains Hytti I and Juva I (Table 8). These two strains were harvested under normal conditions, whereas Lemi was not harvested until about 3 weeks after ripening. During this interval, abundant rains resulted in a heavy infection with neck rot and consequently storage losses due to rotting were high.

The appearance of roots in onions during storage seemed to be principally dependent upon the humidity of the storage chamber. Roots developed only at a temperature of 3—5° C when the relative humidity was 88—94 %. All the other storage chambers were too dry for root formation. Wright *et al.* (1932, 1935) as well as Karmarkar and Joshi (1941) also found that the most important factor influencing rooting was the moisture content of the storage room (cf. p.

57) and that there was no correlation between sprouting and rooting of onions in storage.

Considerable differences in root formation were observed between the various strains. Hytti I was definitely the most liable to root; in this strain almost 100 % of the onions had rooted at the end of almost every storage period. As has been previously mentioned, the strain Hytti I is also very liable to sprout in storage. Likewise, MAGRUDER *et al.* (1941 b) found that those cultivars which form roots early also sprout readily. In contrast to sprouted onions, those which have produced roots do not completely lose their market value.

The best storage temperatures for marketable onions proved to be low, the best results being found at a temperature of —1° C. Similar results have also been obtained in other countries (e.g. BOSWELL 1924 b, WRIGHT *et al.* 1932, CLEAVER 1934, PLATENIUS *et al.* 1934, WRIGHT *et al.* 1935, BREMER 1937, MAGRUDER *et al.* 1941 b, KARMARKAR and JOSHI 1941, COLBY *et al.* 1945, van BEEKOM 1952, YAMAGUCHI *et al.* 1957). The storage temperature can apparently be kept quite low without damage to the onions, providing that they are thawed slowly (LUTZ 1935). For example, WÄCHTER (1908) found that the onion cultivar Zittauer Riesen kept very well during 10-day treatment at —7° C; in only a few of the onions had some of the outer scales frozen. There may be varietal differences in this respect, however. In general, it is not desirable to lower the storage temperature below —3° C, at least not for long periods of time.

One of the most important prerequisites for the good keeping of onions is thorough drying before storage. This has been clearly established in many investigations (e.g. WALKER 1925, HOYLE 1948, JAMALAINEN 1952, van DOORN 1955, KNOBLAUCH 1959 a). A dry and constricted neck of the onion provides effective protection against neck rot (WALKER 1925, 1926).

The effect of ripening on the keeping quality of onions

It is known that immature and insufficiently ripened onions keep poorly in storage. Mention has previously been made of the effect of ripening on sprouting in storage. It has also been found that immature onions are susceptible to decay (BOSWELL 1924 b, WALKER 1926, MAGRUDER *et al.* 1941 b, HELLMERS 1943, COLBY *et al.* 1945, RØED 1950). Likewise, the weight loss during storage is greater in immature than in mature onions (KARMARKAR and JOSHI 1941).

The short growing season in Finland limits the possibilities for ripening of onions. Since onions are generally planted out late in this country in order to prevent flowering, the cool, rainy weather commonly occurring at the end of the summer and autumn, as well as the steadily shortening days, tend to retard the normal course of bulbing and ripening, especially in unfavourable years. The slow ripening of onions under conditions in this country is apparent from

Table 9. Onion planting date trial at Tikkurila, 1953. Onion strain: Kuusamo. Average set weight 18—20 g; storage 20° C; size of trial plots 3.1 m²; 4 replicates; harvested 9—10. 9.

Taulukko 9. Sipulin istutusaikakoe Tikkurilassa 1953. Sipulikanta: Kuusamo; istukkaan keskim. paino n. 18—20 g; säilytys 20° C; koeruudut 3.1 m²; kerranteita 4; korjuu 9—10. 9.

Planting date *Istutusaika*	Yield *Sato* kg/a	rel. *sl.*	Av. weight of bulbs *Sipulin keskim. paino* g
12.5	198.4	100	26.6
19.5	163.5	82	20.7
26.5	156.1	79	19.8
2.6	80.4	41	11.1

F-value 24.49*, least significant yield difference 35.8 kg/a
F-arvo 24.49, pienin merkitsevä satoero 35.8 kg/a*

the fact that it is often necessary to harvest the crop before it has been able to mature; at the time of harvesting most of the roots of the plants are generally still alive and growing. Early planting is therefore to be recommended. It is worth noting that early planting not only improves the quality of the onion harvest but also increases the yield (Table 9). The onion is a plant which effectively utilizes spring moisture but requires warm and dry conditions during the latter part of its growth period.

Flowering of onions caused by cool weather can be prevented by sprouting the sets under varm conditions immediately before planting. This treatment has also been found to improve the keeping quality of the bulbs (Aura 1958). Under weather conditions when ordinary onion plants were unable to ripen completely, those which had been given the artificial sprouting treatment gave considerably higher yields. In these cases pre-sprouting had a decisive effect on the keeping quality of the onions (Table 10). In order for the pre-sprouting treatment to be successful, however, it is essential that after planting in the field the onions should not suffer from lack of moisture, owing to injury to their roots or to dry weather conditions. Pre-sprouting can apparently be replaced by the use of a plastic cover in the field; this effectively warms the surface layers of the soil and prevents evaporation of the soil moisture. In an observation trial carried out at Lohja in 1961, it was found that a plastic cover kept on the ground for 7 days hastened the sprouting of the onion plants by 3—4 days.

Summary

The trials were carried out with three Finnish onion strains (Hytti I, Juva I and Lemi).

The best storage temperature for marketable onions proved to be —1° C. Sprouting of onion bulbs was most abundant at 9—13° C and decreased at

Table 10. Pre-sprouting and storage trial of onions at the Arctic Circle Agricultural Experiment Station, 1958/59. Planted out 15. 6.; harvest 20. 9. 58; size of trial plots 4.5 m²; distance between sets 30×30 cm; 3 replicates. The onions were dried at 25—32° C and stored at 20—24° C during the 1958/59 storage period. Onion strain: Hytti I. The sets were sprouted in moist peat moss immediately before planting.

Taulukko 10. Sipulin idätys- ja varastoimiskoe Perä-Pohjolan koeasemalla v. 1958/59. Istutus 15. 6.; nosto 20. 9. 58; koeruudut 4.5 m²; istutusetäisyys 30×30 cm; kerranteita 3 kpl. Sipulit kuivattu 25—32° C lämmössä ja varastoitu säilytyskaudeksi 1958/59 20—24° C lämpötilaan. Sipulikanta: Hytti I. Idätykset suoritettu kosteassa turvepehkussa välittömästi ennen istutusta.

Treatment *Koejäsen*	Yield *Sato* kg/a	rel. *sl.*	Ripeness *Tuleentuminen* (1—5)	Onions stored *Varastoitu* no. *kpl.*	kg	Sprouting losses *Versomistappio* % no. *kpl.-%*	Decay losses *Mädäntymistappio* % no. *kpl.-%*
Non-sprouted *Idättämätön*	135.5	100	1.5	628	18.3	3.9	70.5
Sprouted 1 week *1 viikon idätys*	166.2	123	3.0	613	23.7	3.5	21.7
Sprouted 2 weeks *2 viikon idätys*	181.7	134	4.5	579	24.6	2.1	9.5

F-value 7.36*, least significant yield difference 38.3 kg/a
F-arvo 7.36, pienin merkitsevä satoero 38.3 kg/a*

both higher (20—31° C) and lower (—1 — +5° C) temperatures. The humidity of the storage chamber had no effect on the sprouting of the bulbs.

Decay losses in storage were principally due to damage caused by neck rot (*Botrytis allii* Munn). Differing storage temperatures had practically no effect on the percentage of onions rotting. At low temperatures (—1 — +5° C) the bulbs decayed much more slowly than at high temperatures (20—31° C). In cool storage (3—5° C) a high moisture content increased the numbers of rotted onions.

The development of roots in the onions — in contrast to sprouting — was found to be mainly dependent upon the humidity of the storage chamber. Roots were formed only when the humidity was very high, approaching saturation.

Under unfavourable weather conditions when untreated onions were unable to ripen completely, sets receiving pre-sprouting treatment gave considerably higher yields. This treatment also greatly improved the keeping quality of the onions harvested.

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SELOSTUS

Tutkimuksia Suomessa viljellystä kasvullisesti lisätystä sipulista, erityisesti sen kukinnasta ja varastoinnista

Klaus Aura

Maatalouden tutkimuskeskus, Kasvitautien tutkimuslaitos, Tikkurila

I. Suomalaiset vegetatiivisesti lisätyt sipulikannat (s. 3)

Tutkimuksessa selviteltiin 27 suomalaisen paikallisen, vegetatiivisesti lisätyn sipulikannan (*Allium cepa* L.) ominaisuuksia. Arvioinnit perustuivat pääasiassa viljelykokeisiin.

Paikallisten sipulikantojen kesken ilmeni selvä korrelaatio sipulin koon ja jakautumisen välillä: isokokoisimmat kannat jakautuivat niukimmin ja pienikokoisimmat runsaimmin (taulukko 1, kuva 2). Kyseiset kannat osoittautuivat jakautuvan kahteen tyyppiin, suurikokoisiin ja niukasti jakautuviin eteläsuomalaisiin kantoihin sekä pienikokoisiin ja runsaasti jakautuviin pohjois-suomalaisiin kantoihin (taul. 1, kuvat 1—3).

Paikallisten sipulikantojemme pääosan pääteltiin polveutuvan Venäjällä alunperin siemenestä viljellystä sipulista.

II. Kukinnon aiheiden synty ja esiinkasvu (s. 15)

Kukinnon aiheet syntyvät sipuleihin yleensä varastoinnin aikana. Kukintaan johtava vanan pituuskasvu alkaa varsinaisesti vasta istutuksen jälkeen. Tutkittavana oli erilaisten varaston lämpötilojen (— 1° C, 3—5° C, 21° C ja 31° C) vaikutus kukinnon aiheiden syntymiseen ja niiden esiinkasvuun. Aineistona käytettiin kahta kotimaista sipulikantaa (Hytti I ja Juva I); istukkaan koko oli 40—60 g.

Varastoinnin aikana syntyi kukinnon aiheita vain 3—5° C:ssa ja 9—13° C:ssa. Ensimmäiseksi alkoi kukinnon muodostus 9—13° C:n varastossa. Noin kahden kuukauden kuluttua varastoinnin alkamisesta (joulukuun puolessavälissä) todettiin ensimmäiset kukinnon aiheiden syntymiseen viittaavat merkit. Tällöin oli noin puolet tutkituista kasvupisteistä muuttumassa reproduktiivisiksi (kuva 4). Kuukautta myöhemmin oli pisimmälle ehtineissä aiheissa kukinnon suojuslehden aihe jo kokonaan syntynyt ja ympäröi koholla olevan kasvupisteen (kuva 5). Kärkisilmussa ja vanhimmassa hankasilmussa oli kukintojen kehitys selvästi pitemmällä kuin nuoremmissa hankasilmuissa. Varastoimiskauden lopulla oli vanojen pidentyminen jo alkanut ja pisimmät kukinnon aiheet olivat 9—11 mm:n pituisia (kuva 7). Pieniin istukkaisiin (10—20 g) syntyivät kukinnon aiheet myöhemmin kuin suurikokoisiin (yli 40 g).

3—5° C:n varastossa tapahtui kukinnon muodostus 1 ½ — 2 kk myöhemmin kuin 9—13° C:ssa (kuva 4). Säilytyskauden lopulla osoittautui, että pisimmällekään kehittyneet aiheet eivät vielä olleet saavuttaneet kuvan 6 esittämää vaihetta.

Molemmissa lämpötiloissa (9—13° C ja 3—5° C) syntyi jokaisen kukinnon aiheen viereen, siis viimeisen (ylimmän) kasvulehden aiheen hankaan, silmun aihe (kuva 6).

Varastoinnin aikana syntyneiden kukinnon aiheiden esiinkasvu on Suomessa sangen nopeata. Esiinkasvun alkaminen istutuksesta lukien vaihtelee meillä runsaasta kahdesta viikosta kuukauteen. Toistaiseksi ei ole ollut tietoja siitä, missä määrin varastoinnin aikana syntyneet kukinnon aiheet kasvavat oloissamme esiin.

Analyysista, joka oli tehty eräästä vuoden 1961 kenttäkokeesta, ilmeni, että kun Juva I -sipulia säilytettiin 9—13° C:ssa, suurin osa (79 %) varastoinnin aikana syntyneistä kukinnon aiheista estyi esiinkasvussaan ja tuhoutui (kuva 8). Sama ilmiö todettiin, joskin vähäisempänä, tutkittaessa eräitä 3—5° C:ssa säilytetyistä istukkaista kasvaneita kasveja. Tuhoutumisen (kuva

9) oli todennäköisesti aiheuttanut nopeasta sipulinmuodostuksesta johtunut vanan pituuskasvun hidastuminen ja sipulilehtien turpoaminen. Tällöin kukinnon aiheen viereen syntyneen hankasilmun lehdet puristivat nuoren kukinnon litteäksi ympäröiviä sipulilehtiä vasten. Tärkeimmäksi nopean sipulinmuodostuksen aiheuttaneeksi tekijäksi on katsottava istukkaiden alhainen säilytyslämpötila (kuva 10).

Lämpökäsiteltyjen (9—13° C + 2 kk 28° C) sipuleiden kukinnon aiheita tuhoutui niin ikään, mutta vähän, koska suurin osa vanoista ehti kasvaa esiin ennen sipulinmuodostuksen alkua.

Istukkaiden jatkuva kylmäsäilytys (3—13° C) saattaa jopa vähentää sipulin kukintaa (kuvat 8 ja 20). Vuoden 1961 kokeesta tehdyn analyysin mukaan se, että 9—13° C:ssa säilytetty sipuli kukki niukemmin kuin lyhyen lämpökäsittelyn saanut, johtui kukinnon aiheiden esiinkasvun estymisestä (kuva 8). Voidaan siis todeta, että jatkuva kylmäsäilytys (3—13° C) ehkäisee Juva I -sipulikannan kukinnon esiinkasvua välillisesti nopeuttamalla sipulinmuodostusta.

Korkeilla kasvulämpötiloilla (20—29° C) todettiin olevan sipulinmuodostuksesta riippumaton ehkäisevä vaikutus kukinnon aiheiden esiinkasvuun.

III. Kasvullisten muodostumien syntyminen kukintoihin istukkaiden lämpökäsittelyn seurauksena (s. 25)

Sipulin lämpökäsittelykokeissa on useana vuotena ilmaantunut käsitellyistä istukkaista kehittyneisiin kukintoihin kasvullisia muodostumia. Vuosien 1960—61 kokeista tehtiin tätä ilmiötä selvittävät tarkemmat havainnot.

Tutkimuksissa käytettiin Hytti I ja Juva I -sipulikantoja. Istukkaat säilytettiin varastoimiskauden (7 ½ — 8 kk) alussa kylmässä (3—5° C) tai viileässä (9—13° C) varastossa. Ennen istutusta niille annettiin eripituisia (1 ½ — 6 kk) lämpökäsittelyjä (21° C, 28° C ja 31° C). Lämpökäsittelyt 28° C:ssa ja 31° C:ssa aiheuttivat molemmissa sipulikannoissa sipulimaisten itusilmujen muodostumista kukintoihin (kuvat 11—14). Eniten niitä syntyi 31° C:n käsittelyn jälkeen. Kukinnan määrä yleensä väheni, mutta itusilmullisten kukintojen osuus lisääntyi käsittelyajan pidetessä (kuvat 11—13). 1 ½ kk:n mittainen käsittely 21° C:ssa ei johtanut itusilmujen syntymiseen, vaan aiheutti ainoastaan kukinnon suojuslehden vihertymistä ja lievää pidentymistä.

Lämpökäsittelyjen seurauksena syntyneitä vegetatiivisia kukintoja esiintyi useita eri tyyppejä (kuvat 15—16).

Selostettavina olevissa kokeissa esiintyneiden itusilmujen syntyminen voidaan katsoa varasto-oloista aiheutuvaksi. Riittävän pitkäaikaisen, alhaisessa lämpötilassa tapahtuneen varastoinnin jälkeen kehittyy istukkaisiin kukinnon aiheet. Toisaalta tiedetään korkeiden varaston lämpötilojen olevan edullisia sipulin vegetatiiviselle kehitykselle. Kun kylmässä (3—13° C) säilytetty istukas siirretään korkeaan lämpötilaan (28—31° C), on ilmeistä, että juuri kukinnon muodostukseen siirtymässä oleva kasvupiste voi palautua vegetatiiviseksi, kasvulehden aiheita synnyttäväksi. Jos taas kukinnon aihe on lämpökäsittelyn alkaessa pitemmälle kehittynyt, voi sen kasvusolukko palautua joko kokonaan tai osittain itusilmuja synnyttäväksi.

IV. Säilytyslämpötilojen vaikutus kukintaan ja satoon (s. 30)

Tutkimuksessa selviteltiin eri säilytyslämpötilojen sekä lämpö- ja kylmäkäsittelyjen yhdistelmien vaikutusta sipulin satoon ja kukinnan (esiin kasvaneiden kukintovanojen) runsauteen. Kokeet suoritettiin neljällä suomalaisella sipulikannalla (Hytti I, Juva I, Juva II sekä Lemi) suurikokoisia istukkaita (yli 30 g) käyttäen.

Kukinta oli yleensä runsainta 9—14° C:n, jonkin verran niukempaa 3—5° C:n ja aivan vähäistä — 3 — 0° C:n säilytyksen jälkeen; varaston lämpötilan ollessa 20—31° C ei kukkimista yhtä poikkeusta lukuun ottamatta ilmennyt lainkaan (taulukot 2 ja 3, kuvat 17, 23, 25 ja 29).

Parhaat satotulokset saatiin useimmiten 20—22° C:n säilytyksen jälkeen. Pakkassäilytys (— 3 — 0° C) osoittautui tässä suhteessa selvästi lämpösäilytystä epäedullisemmaksi silloinkin, kun kukintaa ei ilmennyt (taulukot 2 ja 3, kuva 29). Kylmäsäilytys (3—14° C) johti säännöllisesti erittäin suureen sadon vähentymiseen (kuvat 17, 23, 25 ja 29).

Kylmäsäilytystä (3—5° C ja 9—14° C) seuraavan, kukinnan ehkäisemiseksi riittävän lämpökäsittelyn (28° C) pituus riippui ratkaisevasti alkusäilytyksen lämpötilasta: kun se oli 9—14° C tarvittiin 5—6 kk:n käsittely, mutta 3—5° C:n alkusäilytyslämpötilan jälkeen oli 3 ½ — 4 kk:n lämpökäsittely yleensä riittävä (kuvat 18, 19, 23 ja 25). Suuret istukkaat tarvitsivat pitempiaikaisen lämpökäsittelyn kuin pienet (kuva 27).

Lämpökäsittelyn pidetessä lisääntyi sekä kukinnollisten että kukinnottomien sipulien paino (kuvat 20, 24 ja 26) sekä sato tiettyyn rajaan saakka (kuvat 18, 19, 20, 23 ja 25). Tämä raja saavutettiin aikaisemmin (lyhyemmän lämpökäsittelyn jälkeen) silloin, kun alkusäilytyksen lämpötila oli 3—5° C (kuvat 19 ja 23). Sipulin koon kasvu ja satotuloksen lisääntyminen perustuivat lämpökäsittelyn aiheuttamaan sipulinmuodostuksen ja tuleentumisen myöhästymiseen ja niistä johtuvaan kasvuajan pidentymiseen. Istukkaat, joille oli annettu niin pitkäaikainen lämpökäsittely, että kukinta oli estynyt, antoivat jokseenkin yhtä suuren sadon kuin jatkuvasti lämpösäilytetyt (kuvat 23 ja 25).

Kun eripituiset (4—6 kk) istukkaiden lämpökäsittelyt (20° C ja 31° C) annettiin varastoimiskauden alussa ennen kylmävarastointia (3—5° C), osoittautui, että ratkaiseva vaikutus sipulin kukintaan oli lämpökäsittelyn lämpötilalla: 20° C:n käsittelyä seurasi huomattavasti runsaampi kukinta kuin 31° C:n (kuva 21). Sato samoin kuin kukinnollisten ja kukinnottomien sipulien paino väheni, kun kylmäsäilytys piteni (kuvat 21 ja 22). Tämä vähennys oli pienempi silloin, kun istukkaiden alkusäilytys tapahtui 31° C:ssa. Kylmäsäilytys nopeutti sipulin tuleentumista ja sitä enemmän mitä kauemmin käsittely jatkui. Tuleentuminen nopeutui enemmän silloin, kun alkusäilytys oli tapahtunut 20° C:ssa.

Välittömästi ennen istutusta suoritettu lämpökäsittely osoittautui samanpituista säilytyskauden alussa annettua lämpökäsittelyä selvästi edullisemmaksi.

Koe, jossa pyrittiin selvittämään, voidaanko kylmäsäilytystä (3—5° C) seuraava lämpökäsittely korvata pakkaskäsittelyllä, johti osittain kielteiseen tulokseen. Sato tosin lisääntyi, kun käsittelyaika piteni, mutta kukinta oli runsasta vielä 6 kk:n käsittelyn jälkeen (kuva 28). Myös pakkaskäsittelyn satoa lisäävä vaikutus perustui sipulinmuodostuksen myöhästymisestä johtuvaan kasvuajan pidentymiseen.

V. *Kylmän kasvukauden vaikutus kukintaan (s. 44)*

Eri sipulilajikkeiden ja -kantojen kukkimistaipumus saattaa suuresti vaihdella. Tämä kävi selvästi ilmi Lohjalla kylmänä kasvukautena 1962 (kesä-, heinä- ja elokuun keskilämpötilat 12.4°, 14.9° ja 13.1° C) järjestetyssä, 25 sipulikantaa käsittävässä kokeessa. Sipulikannoista oli 24 kotimaista ja 1 saksalaista alkuperää. Kokeessa käytetyt istukkaat olivat lämpökäsiteltyjä, joten niiden voidaan katsoa olleen istutuksen aikaan vegetatiivisessa tilassa. Koealueen maalajina oli jäykkä savi.

Tulokset osoittivat, että lähes kaikki sipulikannat kukkivat; ainoastaan kolme sipulikantaa, Lemi, Hytti II ja Parikkala, oli täysin kukkimatta (taul. 4). Kantojen välillä ilmenneet kukkimiserot johtuivat niiden erilaisesta perinnöllisestä taipumuksesta muodostaa kukinnon aiheita istutuksen jälkeen. Kukkimattomissa ja niukasti kukkivissa kannoissa ei todettu lainkaan tai todettiin vain vähän kasvussaan estyneitä ja ylimmän lehtiaiheen hankaan syntyneen silmun syrjäyttämiä kukinnon aiheita (s. 20—22). Toisaalta näitä estyneitä kukintoja oli varsin paljon eräissä runsaasti kukkivissa kannoissa (taul. 4). Todennäköisesti aiheita olisi tuhoutunut enemmänkin, jos keskikesä olisi ollut lämpimämpi ja niukkasateisempi ja sipulinmuodostus siten nopeampaa. Koemaana ollut savimaa oli lisäksi omiaan hidastamaan sipulinmuodostusta.

Kasvukauden aikana syntynyt ja esiinkasvussaan estynyt kukinnon aine ei aina tuhoudu hankasilmun puristukseen, vaan saattaa joskus säilyä enemmän tai vähemmän vioittumattomana sipulin sisällä.

Idättämällä istukkaita lämpimissä kasvuoloissa 1—2 viikon ajan voidaan koleista säistä johtuvaa kukintaa huomattavasti vähentää (AURA 1958, vrt. taul. 5). Kukinnan väheneminen perustunee lämpöidätyksen kukinnon aiheiden syntyä ehkäisevään jälkivaikutukseen. Samanlainen vaikutus oli korkeilla säilytyslämpötiloilla (30—31° C), mutta alhaisemmilta (20—22° C, taul. 5, kuva 21) sellainen vaikutus puuttui.

VI. Päivän pituuden vaikutus sipulin kasvuun ja kehitykseen Suomessa (s. 49)

Tutkimuksessa selviteltiin lyhytpäiväkäsittelyn (10 t) vaikutusta kukkimattomiin (lämpökäsiteltyihin) ja kukkiviin (kylmäkäsiteltyihin) sipuleihin (Hytti I ja Juva I).

Osoittautui, että lämpösäilytetyistä istukkaista kasvaneet kasvit eivät jatkuvan lyhytpäiväkäsittelyn johdosta muodostaneet sipulia (kuva 30). Sipulinmuodostus oli epätäydellistä ja suurin osa kasveista jatkoi kasvuaan myöhään syksyyn, kun käsittely annettiin joko kasvukauden alku- tai loppupuoliskolla.

Epäedullisina kasvukausina saattaa meillä sipulinmuodostus jäädä keskeneräiseksi ja sipuli tuleentumatta syksyä kohti lyhenevän päivittäisen valojakson, koleiden säiden ja sateisuuden vaikutuksesta.

Kukkivilla kasveilla lyhyt päivä aiheutti kukinnon esiinkasvun myöhästymistä. Kukinnot jäivät lyhyiksi ja harvakukkaisiksi; toisinaan niissä tavattiin pieniä versovia itusilmuja (kuva 31).

Lyhyt valojakso lisäsi esiinkasvaneiden kukintovanojen määrää Juva I -sipulilla. Tämä johtui siitä, että normaalissa valojaksossa kasvaneilla kasveilla tuhoutui suuri osa kukinnon aiheista sipulinmuodostuksen aikana.

VII. Sipulin lepokausi erilaisissa varaston lämpötiloissa (s. 53)

Välittömästi tuleennuttuaan eivät sipulit kykene muodostamaan uusia versoja ja juuria, vaikka kasvuolosuhteet olisivat suotuisat. Tätä lepokauden vaihetta voidaan nimittää "täysilevoksi", joka on riippuvainen sisäisistä tekijöistä. Täysilevon päätyttyä sipuli on valmis aloittamaan kasvunsa, mikäli ulkoiset olosuhteet ovat suotuisat. Jos kuitenkin olosuhteet sipulin kasvulle täysilevon päätyttyä ovat epäedulliset, jatkuu sipulin lepotila.

Tutkimukset suoritettiin kahdella kotimaisella sipulikannalla (Hytti I ja Juva I) kasvihuone-, kenttä- ja varastoimiskokeina. Sipulin täysilevon syvyyden mittana käytettiin sitä aikaväliä, joka kului istutuksesta versomiseen (tai juurtumiseen).

Kasvihuonekokeissa ilmeni, että versojen ja juurten täysilepo heikkeni nopeimmin 9—13° C:ssa, 3—5° C:ssa ja 21° C:ssa ja päättyi näissä lämpötiloissa jo varastoimiskauden (7 kk) alkupuoliskolla (kuvat 32 ja 34). Säilytyskauden päätyttyä jatkui täysilepo versojen osalta yhä —1° C:ssa ja 31° C:ssa, tosin heikentyneenä.

Kenttäkokeiden tulokset vahvistivat kasvihuonekokeissa saavutettuja. Kenttäkokeissa ilmeni, että hitaimmin kasvun alkuun pääsivät pakkasessa säilytetyt sipulit; myös korkeat lämpötilat (28—30° C) myöhästyttivät selvästi versomista (taul. 6). Kun säilytystä 28° C:ssa seurasi varastointi 9—13° C:ssa, sipulit versoivat nopeammin kuin siinä tapauksessa, että säilytystä jatkettiin 3—5° C:ssa (taul. 7). Tämä viittaa siihen, että täysilepo heikkenee nopeammin 9—13° C:ssa kuin 3—5° C:ssa (vrt. kuva 32).

Varastoimiskokeet osoittivat, että 9—13° C:n lämpötila vaikutti tutkituista lämpötiloista (—1° C, 3—5° C, 9—13° C, 20—22° C, 28° C ja 31° C) haitallisimmin sipulin versojen lepotilan jatkumiseen jälkilepona (kuva 33). Tässä lämpötilassa säilytetyt sipulit versoivat runsaasti jo varastoimiskauden alkupuolella. Huomattavasti paremmin pysyivät lepotilassa 3—5° C:ssa ja 20—22° C:ssa säilytetyt sipulit. Täysin katkeamatta näytti lepotila jatkuvan

— 1° C:ssa, 28° C:ssa ja 31° C:ssa varastoidulla sipulilla. Juuria ilmestyi varastoinnin aikana ainoastaan 3—5° C:ssa säilytettyihin sipuleihin. Tämä johtui kyseisen varaston suuresta suhteellisesta kosteudesta (yli 88 %).

VIII. Ruokasipulin säilytys (s. 59)

Tutkimukset suoritettiin kolmella suomalaisella sipulikannalla (Hytti I, Juva I sekä Lemi). Edullisimmaksi varaston lämpötilaksi todettiin — 1° C. Sipulin versominen oli runsainta 9—13° C:ssa ja väheni sekä korkeammissa (20—31° C) että alhaisemmissa (— 1 — + 5° C) varaston lämpötiloissa (taulukko 8). Varaston kosteus ei vaikuttanut sipulien versomiseen.

Mädäntymistappiot johtuivat suurimmaksi osaksi sipulin harmaahomeen (*Botrytis allii* Munn) aiheuttamista vahingoista. Varaston lämpötilat eivät vaikuttaneet sanottavasti mädäntyneiden sipulien lukumäärään. Alemmissa lämpötiloissa (—1 — +5° C) mädäntyminen tapahtui kuitenkin huomattavasti hitaammin kuin korkeammissa (20—31° C). Kosteus lisäsi sipulien mädäntymistä.

Juurten kehittyminen sipuleihin osoittautui, päinvastoin kuin sipulien versominen, riippuvaksi lähinnä varaston kosteudesta. Sipuleihin ilmestyi juuria ainoastaan ilman kosteuspitoisuuden ollessa suuri.

Oloissa, joissa sipuli ei kunnolla ehdi tuleentua, saatiin istukkaiden esi-idätyksellä huomattavia sadon lisäyksiä. Idätys vaikutti tällöin ratkaisevasti myös sipulisadon säilyvyyteen (taul. 10).