DISSERTATION

BULB INITIATION IN THE ONION PLANT, ALLIUM CEPA

Submitted by

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WE HEREBY RECOMMEND THAT THE DISSERTATION PREPARED UNDER OUR SUPERVISION BY FATHI ABDEL-GABER AHMED ENTITLED BULB INITIATION IN THE ONION PLANT, ALLIUM CEPA BE ACCEPTED AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

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ABSTRACT OF THESIS

BULB INITIATION IN THE ONION PLANT, ALLIUM CEPA

1. The study was conducted to evaluate various methods of determining when bulbing is initiated in the onion plant, Allium cepa L. Evaluation was on the basis of accuracy, reliability, and simplicity. Methods of determining when bulb initiation has taken place are necessary for further research on bulbing, to develop field modifications of bulb initiation and development, to facilitate selection of breeding material, and to develop methods of predicting bulb maturity. Forty-four cultivars were grown under several environmental conditions. Reduction in the maximum ratio (in a given plant) of the foliage leaf blade length to sheath length almost always preceded internal scale formation. Prediction of internal scale formation occurred in greenhouse grown plants when this ratio was 10 or less. The same value for the youngest visible leaf can be used for this purpose in field grown plants. Other less reliable indices were means of youngest visible and maximum leaf ratios and corresponding sheath lengths, external minimum leaf ratios, base/neck ratios, number of visible leaves and plant height.

2. Effects of planting dates on bulbing were studied by planting seeds of the variety 'White Portugal' in the field at weekly intervals,

from April 15 to May 6, 1968. Plants four weeks apart in age began bulbing less than a week apart. The increased responsiveness to increasing daylength may have been due to increasing temperature or plant age. However, higher percentages of plants bulbed in earlier than in later plantings.

3. Effect of temperature on bulb initiation was demonstrated by plants of the hybrid 'B 2190 A x Colorado 6' grown in the greenhouse and outdoors. Results indicated that the photoperiodic stimulus was more effective at higher temperatures.

4. Incandescent light interruptions for an hour at midnight, continuously or for a period of two weeks when plants were 12 weeks old, induced early bulbing. Other plants received the two weeks of night interruption when they were 4, 6, 8 and 10 weeks old. Older plants responded better to night interruption. The hybrid 'B 2190 A x Colorado 6' was used in this study.

In another experiment, using the same hybrid, plants were exposed to 1) naturally prevailing daylength (14 to 13 hours), 2) nine hours of natural daylight, and 3) naturally prevailing daylength plus continuous night interruption for an hour with incandescent light at midnight. All plants exposed to night interruption bulbed; but no bulbing was found in the other treatments. Distinct morphological differences were observed between plants exposed to the three treatments. The night interruption treatment resulted in plants significantly higher in base/neck ratios, lower in youngest visible and maximum leaf ratios and longer corresponding sheath lengths and fewer visible leaves than produced by the other two treatments. The tallest plants resulted from the first treatment. Longer photoperiods resulted in an increase in plant height, number of visible leaves and reductions in both youngest visible and maximum leaf ratios.

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INTRODUCTION

The morphological symptoms of bulb initiation in the onion plant have been studied by many workers. As early as 1925, the growth pattern of the root system as related to bulb initiation was investigated. Later several workers found that the increase in leaf sheath length relative to their blades accompanied initiation. Recently, several workers used these blade/sheath ratios in constructing graphs to diagnose either bulb initiation or the degree of bulbing attained. The procedure of constructing graphs is tedious and time consuming. The measurement of plant base and neck diameters to obtain the bulbing ratio was investigated by some workers and was found not to be an accurate procedure under varying conditions. In addition, it has been impossible to specify at which bulbing ratio bulb initiation occurs.

One objective of the present study was to evaluate various bulb initiation symptoms in different environments. Photoperiod and temperature are both known to affect bulb initiation. The relationships between these two environmental factors and the importance of plant age in modifying environmental effects were studied.

The order of events had not been understood enough to know the first observable symptom; therefore, a second objective of this study was to examine the temporal relationships of several initiation symptoms. Further research on bulb initiation and possible field modification of time of bulb initiation or development would likely benefit from being able to determine precisely when initiation has taken place.

Prediction of the time of maturity of the onion plants, as early as possible during the growing season, is of commercial significance and can be utilized by onion breeders. Relationships between maturity and characters used for early diagnosis of bulb initiation were studied as a third objective.

The fourth objective was selection of a reliable bulb initiation symptom for field use. There are commercial needs for determining when initiation occurs. The method used should be simple and preferably one that can be accomplished with minimum equipment.

REVIEW OF LITERATURE

Onion Plant Development

The emergence of leaves from germinating onion seed is described by Hoffman (1933), Hector (1936) and Hayward (1938). As the epicotyl grows, the first foliage leaves elongate rapidly until the first foliage leaf pushes its way through a small slit in the epicotyl. The second and subsequent leaves emerge through oppositely located slits, so that the visible leaves alternate in position. The vertical cylindrical base of each young leaf completely surrounds younger leaves which in turn enclose the apical meristem.

The development of the bulb is recognized by the thickening of the base of the seedling. This is the result of swelling of the base of the pseudostem and the formation of scales from leaf initials produced at the stem apex, Heath and Hollies (1965) and Kato (1963 a). Heath and Holdsworth (1948) defined the scale as any leaf initial having the blade shorter than the sheath. Differentiation of leaf initials into scales was found not to occur before length of initials exceeded one mm in onion as reported by Heath and Hollies (1965); and in *Narcissus pseudonarcissus* L., Denne (1960). Jones and Mann (1963) report, however, that in some varieties, namely, 'Excel', as much as one third of the bulk of the whole bulb may be composed of the thickened outer leaves of lateral buds. Generally, this phenomenon is commercially undesirable and can be effectively selected against. This early development of lateral buds was found by Shalaby (1966) to have 64 percent heritability. On the other hand, Ito (1956) found in Japan that poor nutritional conditions and low temperature delayed bulb division.

The thickening of the pseudostem to form the bulb is accompanied by general cessation of foliage leaf development and root formation and activity, according to Sideris (1925). He also found that the onion plant produces first a set of roots, centerally located on the root disc, which gradually disappears by the time bulbing is initiated. The dead roots are succeeded by a new set, produced gradually at the periphery of the stem. Kato (1963 a) noticed that rooting in 'Senshuki' onion plants reached a maximum before thickening of the pseudostem occurred. As the bulb developed, the rate of rooting decreased, so that the weight ratio of top to root increased gradually. Kato (1965 a) found that the removal of about half the roots just below the crown of 'Senshuki' onion plants grown in pots, before bulbing initiation, induced scale leaf formation. The same treatment during a later stage resulted in the inhibition of bulb thickening. Root development and activity were found by Kato (1963 a) to be restricted by long days, high temperature, and bulb development. Heath and Hollies (1965) reported that rooting reduced the degree of bulbing after initiation, possibly by competing for carbohydrates supply.

Defoliation experiments showed that the organ which perceives the light and responds to its duration is the foliage leaf (Heath and Holdsworth, 1948). Kato (1965 a) also found that the bulb formation was retarded, in 'Senshuki' onion variety, by continuous and severe removal of leaf blades, but not by removing few leaves. The removal of alternate expanded leaves prior to bulb formation retarded scale leaf formation, and defoliation during bulb development inhibited bulb thickening. The removal of all leaf blades except the oldest ones caused the emergence of foliage leaves instead of scales, even under inductive long photoperiods.

Working with Narcissus pseudonarcissus L., Denne (1960) described histologically the development of scale and foliage leaves from leaf initials longer than one mm. A scale is formed when cell division is restricted to the base of leaf sheath. Where cell division occurs in the base of the blade, a foliage leaf arises. Leopold (1964) and Aoba (1954), on the other hand, report that bulbing in onion is mainly effected by cell enlargment rather than cell division. Stomata and pallisade tissues developed well in foliage leaf blades, Kato (1963 b). They did not differentiate as well in either foliage leaf sheath or in all parts of the scale leaf. A given position in a foliage leaf sheath contained fewer parenchyma cells and larger intercellular spaces than a corresponding position of a scale leaf. The parenchyma cells in sheaths of scales increased in size, but remained constant and isometric in foliage leaf sheaths. The undifferentiated parenchymatous terminal portion of the scale (reduced blade) developed blade tissues when transferred to conditions unfavorable to bulbing. Conditions favorable to bulbing seem to operate in suppressing the differentiation of blade tissues.

Hormonal control of the bulbing process was postulated by Leopold (1964). Chromatographic studies by Clark and Heath (1959) indicated that the natural auxin present during bulbing is likely to be 3-indolyl acetic acid (IAA). Later, Cockshull and Heath (1962) found that both IAA and sucrose must be supplied to induce bulbing initiation in sections of onion seedlings. Kato (1965 b) was unable to induce bulbing under non-inductive conditions by injecting IAA to leaf blades. Injection of sucrose into leaf blades accelerated bulb development only under inductive long days. He also found that the auxin content of buds and leaf tips increased toward the time of bulbing and reached a maximum on the tenth day following transfer to inductive long days, and then fell below that of plants grown under non-inductive short days. The auxin content increased earlier in an early variety than in a mid-season one, but otherwise the general trend for both varieties was the same. Findings of Clark and Heath (1959) on the course of auxin development toward the time of bulbing show the same trend.

Leopold (1964) reported that the formation of an onion bulb is a consequence of the mobilization of carbohydrates into the bases of very young leaves. Kato (1965 b) found that the nitrogen content of the leaf blade, which was high during rapid increase in plant height, decreased during bulbing. The accumulation of carbohydrates in leaf sheaths reached a maximum during the early stages of bulb formation. Subsequently it decreased, even though the total carbohydrate content of the plant as a whole continued to increase. Further, Kato (1967) reported that sugar accumulation during bulbing is believed to depress respiration and induce bulb dormancy.

Terabun (1967) found that maleic hydrazide at 500 ppm or over induced swelling of basal sheaths and 2, 4-D caused elongation of sheaths without their swelling.

Early Symptoms of Bulbing

Bulbing is initiated by the time the plant has developed a certain number of visible leaves, and the number varies with variety (Hector, 1936). Hoffman (1933) indicated that bulbing is accompanied by the development of leaves with longer sheaths than blades, which were later termed scales by Heath and Holdsworth (1948).

Garner and Allard (1923), McClelland (1928) and Magruder and Allard (1937), adopted visual procedures to assess bulbing. Heath and Holdsworth (1948) reported observing an empty space between sheaths of the small developing initials as an early sign of bulbing. This space arose from the continued growth of the sheath and the cessation of growth of the blade of the next leaf initial within.

Later, the degree of bulbing was estimated as the bulbing ratio (Clark and Heath, 1962). This is the ratio of the greatest diameter near the base to the least diameter at the 'neck' of the plant. This measurement was shown by Heath and Hollies (1965) to be rather variable and did not give a sensitive method of detecting very early stages in bulb development. Further, they reported that bulbing ratio of even non-bulbing plants increases slowly with age. Thus, it was not possible to state at which ratio bulbing was initiated. In late stages of bulbing, the ratio continued to increase despite cessation of base swelling. This increase was due to differential shriveling of the leaf parts which reduces the diameter of the 'neck'.

As a result of the insensitivity of the bulbing ratio procedure, Heath and Hollies, working with sets of some open pollinated onion varieties, namely 'Ebenezer' and 'Rijnoberger' used the development of leaf initials with longer sheaths than blades to assess bulbing. Accordingly, they constructed graphs showing the degree of bulbing at any specific stage of plant growth. This was accomplished by plotting on logarithmic scale the ratio of leaf blade length to its sheath length (leaf ratio) against its number (position) on the seedling, using the leaf initial longer than one mm as a starting point. They met a difficulty, however, in averaging the leaf ratio curves for different plants, when the incidence of bulbing is very variable within a treatment. As a possible solution, though not completely satisfactory, they suggested the use of either the smallest initial measured (about one mm) or the youngest visible leaf as a reference point. Upon adopting the latter alternative, for some of the plants, one or two of the initials were omitted, while some other plants made no contribution to the mean plotted at leaf number one. Mean number of scale leaves per plant or mean minimum leaf ratio was suggested by the authors as a better indication of the degree of bulbing under their experimental conditions. Kato (1963 a) using potted plants of the 'Senshuki' onion variety in Japan, showed that both the curves of the leaf ratios from the outer to the inner leaves and the time required for the plant to reach maximum height may be used to determine the time of scale leaf formation. A rapid increase in the height indicated to him the initiation of bulbing.

Many authors, viz., Aoba (1954, 1962, 1963), Kato (1963 a, b, 1965 a, b), adopted the leaf ratio procedure to determine the degree and the time of bulbing in onion and Denne (1960) in Narcissus pseudonarcissus L.

Factors Affecting Bulb Initiation

Light duration

Since the work of Garner and Allard (1923), it has been recognized that the bulbing of onion Allium cepa L. is more or less dependent on a suitable length of day. Magruder and Allard (1937) showed that although some American and European onion varieties markedly differed in the minimum photoperiodic requirement for bulbing initiation, longer photoperiods consistently induced earlier maturity. Similar findings were reported earlier by McClelland (1928) and Wilson (1932), for some American onion varieties. Abe et al. (1955) found that there was a tendency for regional adaptability of onion varieties in Japan determined by prevailing photoperiod. They also found that production of large bulbs was prevented by excessive daylength, due to the rapid rate of maturation.

Interruption of long inductive photoperiods by short ones, in some Japanese onion varieties, resulted in an increased number of foliage leaves and a decrease in number of scale leaves, as Aoba (1962) showed. The degree of tendency towards vegetative growth, depended on the stage of plant development at which the short day treatment was applied and the duration of such a treatment. It proved possible, according to Kato (1964), to reverse the bulb forming phase even after maturity of the onion plants. Any effects produced by a long inductive photoperiod were nullified by a period of short days.

Light intensity

Low light intensity greatly delays bulbing (Heath and Hollies, 1965). This was explained as being a requirement for an ample supply of sugar. Kato (1964) found in Japan that bulb thickening, but not initiation, was inhibited by a decreased light intensity.

Light quality

Paribok (1957) reported that bulb formation in onions grown from either seed or sets was rapid under incandescent lamps (rich in infrared). With luminescent lamps (rich in red), vigorous vegetative growth with no bulb initiation was induced in some Russian onion varieties. In a detailed study on a Japanese onion variety, Terabun (1965) carried out a series of experiments to elucidate the effect of light quality on the growth of the onion plant and bulb formation. He used plants at the age of about six weeks (from germination). Most of his experiments showed that light of high intensity, for minimum duration, is required to induce bulbing. In addition, red and far-red were found to play a special role in the bulbing process. In order for the light of high intensity to be inducive to bulbing, it should contain the far-red light. Further, red was shown to have an antagonistic effect to far-red, in bulb formation. The antagonistic effect of red and far-red was, however, irreversible, in bulb induction. The general results of Terabun's experiments led him to conclude that bulbing in the onion plant is controlled by two photo-reaction systems, namely, phytochrome and the high energy reaction.

Effects of night interruption

Kato and Oyer (1969) reported on the effect of photoperiod, dark interruption and flashing light on bulbing in 'Early Harvest' and 'Yellow Sweet Spanish' onion varieties. They stated that although onion bulbing is considered a photoperiodically controlled response, the conventional night interruption technique does not stimulate bulbing unless the total illumination is near the critical daylength or the supplemental light is given in flashes throughout the dark period.

Temperature

Clark and Heath (1959) reported an increased bulbing response with increasing temperature, from 15° to 25° C. Imazu et al. (1954) found that in Autumn sown onions in Japan, bulb formation occurred earlier in warmer areas. Late varieties, however, gave better yields in cooler areas, as they started late enough to have accomplished good vegetation in the early growth period. Iwama and Hamashima (1953) also in Japan, found that the most favorable temperature range for bulb development was 18° to 25° C, for both Fall and Spring sown onions. Low temperature in some regions limited bulb formation, as in Fall-sown plants, where bulb formation started much later than the dates when the daylengths became sufficiently long for bulb formation. Kato (1963 a, 1964) also found that the higher the temperature during the long inductive photoperiod, the earlier the bulb developed and the less the roots grew.

Jones and Mann (1963) attributed the noticed differences in bulb yields of onion from year to year to the yearly differences in temperature, with consequent effects on bulbing initiation. They further stated that the low temperature prevailing at high elevations may delay the bulbing of a variety well beyond the date that is usual in warm areas of similar latitude. Low temperatures enable varieties with short day requirement, to develop considerable foliage before bulbing begins. This explains, at least in part, according to Jones and Mann (1963), why short day varieties grown at high elevations make bulbs of good size even under conditions of quite long days.

Plant age and size

Hector (1936) and Hayward (1938) reported that bulbing is noticed when the plants develop a certain number of functioning foliage leaves. Jones and Mann (1963) report that in order to obtain the highest percentage of sound bulbs from transplants, i.e., free from bolters and doubles, seedlings sized from six to eight mm thick and 17 to 25 cm long, are to be used in producing the bulb crop. They, however, further stated that plant size itself does not seem to inhibit the onset of bulbing, if photoperiod and temperature exceed the minimum requirements. As an example, they reported the occurrence of bulbing in plants of the 'Red Creole' onion variety when they had developed one foliage leaf, under conditions exceeding the minimum requirements for photoperiod and temperature. Iwama and Hamashima (1953), on the other hand, reported that seedling age was limiting for bulbing in Japan in some varieties grown under conditions of sufficient daylength and appropriate temperature.

Effect of nutrients supply

Scully et al. (1945) have shown that near the critical photoperiod, onion plants supplied with low nitrogen started bulbing earlier than those receiving a high rate. But within the range of the adequate photoperiod, different rates of nitrogen supply did not affect bulbing. Kato (1964) found that heavy nitrogen applications did not delay bulb formation under excessively long photoperiod (20 hrs.), although it resulted in a smaller bulb. A reverse effect was noticed at less than the critical daylength.

Water supply

Work of De Lis et al. (1967) tentatively indicated an effect of water supply at specific stages of plant growth on bulbing in the onion plant. Drought at the seedling stage, with adequate water at other growth stages, accelerated bulb formation by 15 days.

Interaction between some factors affecting bulbing

Varietal differences in the photoperiodic requirements were reported by Magruder and Allard (1937). Even within a single variety, plants representing different genotypes, were found to react differently to a given photoperiod. Abe et al. (1955) supported these findings. They further stressed the possible significance of their finding in the evolution of different varieties.

Using some American and Japanese onion varieties in Japan, Hamashima (1953) found that bulb formation was controlled by temperature and age of plant in early varieties and daylength and age in late varieties. In the extra early variety 'Aichishiro', bulbs developed even under a short day (10-12 hrs.) if temperature was favorable and plants had attained a certain size. The plant size, necessary to be attained before bulbing could occur, was larger in the late varieties than in the early varieties.

The results of Thompson and Smith (1938) show that bulbing is not determined by daylength alone, but by the interaction of daylength and temperature.

Results of Scully et al. (1945) and Kato (1964) indicate that the effect of nitrogen supply on bulbing is not absolute and was not noticed unless combined with a specific daylength and/or temperature. Nitrogen excess or deficiency did not show up unless thresholds of photoperiod and temperature requirements were prevailing.

Spacing between plants is known to affect a number of micro-environmental elements controlling plant growth and development. Jones (1929) found a distinct effect of spacing on bulbing initiation and final bulb size.

Genotype, photoperiod, temperature and plant age are the most important factors which interact to finally cause onion plants to bulb.

MATERIALS AND METHODS

The following definitions, unless otherwise modified, are used throughout the study for procedures and items defined.

Base/neck ratio (B/N). This ratio is calculated by dividing the diameter of the widest part of the base of the plant by the diameter of the narrowest part of the neck of the plant.

External minimum leaf ratio (EMNLR). This is the smallest leaf ratio of all visible leaves.

Internal minimum leaf ratio (IMNLR). This is the smallest leaf ratio of the leaves internally located in the plant.

Lateral buds. These are the buds, other than the main apex, which grow in some plants to form leaves and scales.

Leaf blade. This is the portion of the leaf distal to the slit through which the next younger leaf emerges.

Leaf sheath. This is the portion of the leaf proximal to the slit through which the next younger leaf emerges.

Leaf ratio. This is calculated by dividing the blade length of a leaf by the sheath length.

Maximum leaf ratio (MXLR). This is the largest leaf ratio among all leaves (longer than one mm) on a plant. The leaf possessing the MXLR was almost always found to be restricted to the youngest visible leaf or the first one to the interior.

Plant height. Plant height is the measurement of the total length from the base of the plant to the top of the tallest leaf, excluding the root system.

Planting. All plants used in these studies were grown from seed.

Scale. Any leaf initial with a sheath longer than, or as long as the blade. This means a leaf ratio of 1 or less.

Visible leaves. These are leaves that can be seen without dissection of the plant.

Youngest visible leaf (YVL). This is the shortest of the visible leaves.

Percent tops down. This is an indicator of onion maturity. It represents the percent of plants in which the tops have fallen prior to bulb maturity.

List of experiments

This study is based on samples from several experiments planted in 1967, 1968 and 1969. Table 1 lists the plantings from which the samples were taken.

Table 1. List of all experiments conducted throughout the present study.

Expt. No.	Locality	Cultivars	Date Planted	Reason other than standard development
1	Greenhouse (Ft. Collins)	2 O. P.* varieties 5 Inbreds 4 hybrids	June 27, 1967	
2	Greenhouse (Ft. Collins)	10 O. P.* varieties	June 29, 1967	
3	Field (Fort Collins)	3 O. P.* varieties 4 inbreds	April 15, 1968	
4	Field (Fort Collins)	White Portugal	April 15, 1968 April 22, 1968 April 29, 1968 May 6, 1968	Date of Planting
5	Field (Fort Lupton)	5 O. P.* varieties 8 inbreds 3 hybrids	April 4, 1969	
6	Greenhouse (Ft. Collins)	B 2190 A x Colorado 6	Jan. 19, 1969	Night interruption and age
7	Greenhouse & Outdoors (Ft. Collins)	B 2190 A x Colorado 6	April 17 May 1, 1969	Temperature and age
8	Greenhouse (Ft. Collins)	B 2190 A x Colorado 6	June 18, 1969	Night interruption and photoperiod
9	Field (Rocky Ford)	23 cultivars	March 31, 1969	Maturity

*O. P. = Open Pollinated

Morphological studies

In 1967 and 1968, seedlings were thoroughly dissected. Sheath and blade lengths were recorded for all leaves longer than one mm on each seedling, and leaf ratios were calculated. For the variety 'White Portugal' and the inbred 'B 2190 B' grown in the greenhouse in 1967 and in the field in 1968, graphs were constructed, showing the mean leaf ratios plotted against their position on seedlings. Leaves were assigned numbers in two ways. Because of differences in leaf number per seedling, the youngest visible leaf was considered a reference point on the seedling in one case. Other leaves were assigned their numbers relative to it. In the other case the innermost leaf was considered leaf number one, and all other leaves were numbered distally from it. In both cases, some of the means of the leaf ratios were not calculated from leaves of all seedlings involved.

Correlation coefficients between maximum leaf ratios and leaf ratios of the youngest visible leaves were computed for the 1967 and 1968 cultivars. These correlations were computed to determine whether or not the more easily determined youngest visible leaf could be used in place of searching for the maximum ratio in each seedling. It was observed that the maximum ratio usually occurred in the youngest visible leaf. For the cultivars 'White Ebenezer', 'White Portugal', 'B 2190 B', 'B 1900 A x B 2190 B' and 'B 1900 A x Colorado 6', correlation coefficients between internal minimum leaf ratios and both youngest visible and maximum leaf ratios were computed. Correlation coefficients between internal minimum leaf ratios and external minimum leaf ratios were also computed for the cultivars 'White Portugal' and 'B 2190 B'. Transformation of the above values to their natural logarithm was necessary to achieve linearity.

For the Winter, Spring, and Summer experiments of 1969, sheath and blade lengths of the youngest visible leaves were recorded. In order to obtain the maximum leaf ratio for each plant, sheath and blade measurements were also taken on the leaf immediately interior to the youngest visible leaf if it had a larger ratio.

Two greenhouse experiments were conducted in the summer of 1967. A 16 hour light period was maintained by supplementary incandescent lamps. Minimum night temperature was 60° F and maximum day temperature was 80° F. Seeds in each experiment were sown into two soil benches (representing replications), in rows three inches apart. Plants were thinned at the age of three weeks, and seedlings were kept about one fourth of an inch apart.

The first experiment included 11 cultivars listed in Table 2. Seeds were sown on January 27, 1967, and weekly sampling was started on July 18, 1967.

Table 2. Cultivars grown in experiment 1.

Cultivar	Cultivar Type	Source
8875 B	inbred	Foskett
1288 A	inbred	"
1288 A X 8875 B	hybrid	"
Colorado 761	inbred	"
2997 A	inbred	"
2997 A X Colorado 761	hybrid	"
2190 B	inbred	"
1900 A	inbred	"
1900 A X 2190 B	hybrid	"
1900 A X Colorado 6	hybrid	"
Colorado 6	open pollinated variety	"

Experiment 2 included 10 open pollinated cultivars, listed in Table 3.

Table 3. Cultivars (open pollinated varieties) grown in experiment 2.

Cultivar	Source
Early White Mexican	Desert Seed Company
Australian Brown	" " "
Red Creole	" " "
Yellow Ebenezer	" " "
Southport White Globe	Harris Seeds
White Portugal	" "
White Lisbon	" "
White Ebenezer	" "
Crystal White Wax	W. Atlee Burpee Company
Excel Bermuda	" " " "

Seeds were sown on June 29, 1967. Samples of three seedlings each were pulled weekly, starting July 20, 1967.

In 1968, two experiments were conducted at Colorado State University Horticulture Farm at Fort Collins. The first consisted of four planting dates of the variety 'White Portugal', replicated four times in a randomized block design. One treatment per week was planted for four consecutive weeks, starting April 15, 1968, in rows three feet apart. Plants were thinned to two inches apart. Starting June 18, 1968, samples of three seedlings per plot, were taken and several morphological measurements were made.

The other 1968 experiment was conducted to study the bulbing behavior of the seven cultivars listed in Table 4.

Table 4. Cultivars grown in experiment 4.

Cultivar	Cultivar Type	Source
White Portugal	O. P. variety	Foskett
54-306 B	inbred	"
White Ebenezer	O. P. variety	"
White Sweet Spanish	O. P. variety	"
Ia 42 B	inbred	"
B 2190 B	inbred	"
B 12115-2	inbred	"

Seeds were sown on April 15, 1968, in single rows, three feet apart. Plants were kept approximately two inches apart by thinning, at the age of about a month. Starting June 19, 1968, weekly samples were obtained. Two samples, three seedlings each were pulled for each cultivar, and several morphological measurements were made.

Monthly mean maximum and minimum temperatures during the growing season of 1968 are presented in Table 5.

Table 5. Monthly mean maximum and minimum temperatures for the growing season of 1968, at Fort Collins.

Month	Mean maximum, °F	Mean minimum, °F
April	56.1	35.2
May	65.6	45.6
June	82.0	52.3
July	84.3	56.9
August	80.7	53.1

Three experiments were conducted during 1969. The winter experiment was designed to study the effect of night interruption on plants at different ages. The night interruption consisted of one hour of light from incandescent lamps, beginning at midnight. Treatments were as follows:

1. Plants kept under prevailing natural daylength, which increased from about nine hours at the beginning of the experiment to about 15 hours at its termination. This treatment was control 1.

2. Plants kept under prevailing natural daylength, plus daily night interruption for the entire experiment. This treatment was control 2.

3. Plants kept under prevailing natural daylength and treated with two weeks' night interruption at the age of four, six, eight, ten and 12 weeks.

Mean maximum and minimum monthly temperatures were as presented in Table 6.

Table 6. Monthly mean maximum and minimum temperature during experiment 6.

Month	Mean Maximum, ^oF	Mean minimum, ^oF
January	60	60
February	60	60
March	60	60
April	65.7	60
May	70.4	60

Samples were taken weekly, starting March 17, 1969. The planting date was January 19, 1969. Seeds of the hybrid 'B 2190 A x Colorado 6' were sown in soil-filled clay pots, 8 inches in diameter. The soil mixture consisted of one part each of peat, sand and loam soil. Two replicates, three pots each, were used for each of the treatments. Plants were thinned at the age of one month, to about one fourth of an inch apart. Analyses of variance were calculated for data recorded and a histogram was constructed.

The Spring experiment was intended to study the effect of temperature and plant age on the bulb initiation process. Seeds of the hybrid cultivar 'B 2190 A x Colorado 6' were sown in rows one inch apart in six inch pots and filled with vermiculite. Sub-irrigation was utilized to provide nutrient solution to the plants and to maintain a uniform moisture content regardless of the treatment. Only water was applied for the first 10 days (until germination). Two replicates, two pots each, were used for each treatment. Treatments were as follows:

1. Planting on April 17, 1969, in the greenhouse.

2. Planting on April 17, 1969, outside the greenhouse.

3. Planting on May 1, 1969, in the greenhouse.

4. Planting on May 1, 1969, outside the greenhouse.

5. Planting on May 1, 1969, in the greenhouse for 10 days then pots were moved outside the greenhouse.

The main environmental factor presumed to differ inside and outside the greenhouse is the temperature regime. Light quality and intensity inside the greenhouse were found by Goldsberry (1967) to be similar to that outside. Natural light duration was the same. Plants were thinned at about one quarter of an inch apart in the rows at the age of one month. Sampling was started May 22, 1969, and was continued weekly. Three seedlings were pulled from each replicate and various observations were recorded. Analyses of variance were calculated and a histogram was constructed.

The Summer, 1969, experiment was designed to further study the effect of night interruption and the length of the photoperiod on the bulb initiation process. Vermiculite-filled six inch pots were used. The sub-irrigation procedure was adopted. Two replicates, one pot each, were used for each treatment. Seeds of the hybrid variety 'B 2190 A x Colorado 6' were sown on June 18, 1969. Pots were left under prevailing greenhouse conditions for two weeks, after which the following treatments were applied.

1. Nine hours of natural light, maintained by covering for the night period.

2. Naturally prevailing light conditions.

3. Naturally prevailing light conditions, plus one hour of incandescent light at midnight.

The natural photoperiod decreased, through the duration of the experiment, from about 14.5 hours (at sowing date) to about 13 hours at the harvest date. The temperatures were similar for all treatments. Minimum (night) temperature was 60° F and maximum averaged 79° F. Plants were all harvested on August 5, 1969. Samples of 10 seedlings each were selected randomly from each replicate. Analyses of variance were calculated.

A 1969 Fort Lupton study (experiment 5) of cultivars was conducted to further study bulb initiation. Samples of five seedlings each were taken from 16 cultivars, weekly throughout the study. Two samples of 10 seedlings each were taken from four cultivars for the last four sampling dates. Names of cultivars grown in the field at Fort Lupton appear in Table 7.

Table 7. Cultivars grown in experiment 5.

Cultivar	Cultivar Type
B 2190 B	inbred
Australian Brown	O. P. variety
Ia 2997 B	inbred
B 2190 B	inbred
B 2215	inbred
Southport White Globe	O. P. variety
Ia 42 B	inbred
B 1900 B	inbred
B 5546 B	inbred
P 54-306 B	inbred
White Sweet Spanish	O. P. variety
White Ebenezer	O. P. variety
B 2108 B	inbred
(B 2264 x Colorado 6) X Colorado 6	backcross
Ia 42 A x Colorado 6	hybrid
B 2108 A x Ia 2997 B	hybrid

Seeds of the above cultivars were sown in single rows, on April 4, 1969, and sampling was begun on July 24, 1969. Natural photoperiod increased from about 12 hours at planting date to about 15 hours on June 21, when it began decreasing to about 13 hours in August. Temperatures found during the growing season are presented in Table 8.

Table 8. Monthly mean maximum and minimum temperature during experiment 5.

Month	Mean maximum, ^{o}F	Mean minimum, ^{o}F
April	66.9	34.4
May	73.0	42.8
June	74.7	48.8
July	89.8	57.0

Morphological measurements were recorded for the samples of Fort Lupton cultivars and means were calculated.

An attempt was made to determine the relationships among various observations recorded for samples of cultivars. Maturity (percent tops down on August 28) and bulb diameter, bulb height, and shape index (diameter/height ratio) were noted, along with the previously mentioned morphological measurements. Materials grown at the Rocky Ford Branch Experiment Station of Colorado State University were used for these purposes. The Branch Experiment

Table 9. Cultivars grown in experiment 9.

Cultivar	Cultivar Type	Company
Hybrid Fiesta	hybrid	Campbell
Sweet Spanish, Colorado 6	O.P. variety	"
Southport White Globe	" "	Burpee
Sweet Spanish Yellow Utah	" "	"
White Sweet Spanish	" "	"
Colorado 6	" "	Waldow
White Sweet Spanish	" "	"
Hybrid 90	hybrid	"
Hybrid 60	"	"
Hybrid P. W. 101	"	Pietere-Wheelers
Sweet Spanish Las Animas	O.P. variety	Northup-King
Hybrid Chieftain	hybrid	Keystone
White Sweet Spanish Utah Jumbo	O.P. variety	"
Yellow Sweet Spanish Colorado No. 6	" "	"
Yellow Sweet Spanish Utah Jumbo	" "	"
Southport White Globe	" "	"
White Ebenezer	" "	"
Hybrid Granada	hybrid	Asgrow
Southport White Globe	O.P. variety	"
Hybrid Autumn Splender	hybrid	"
Yellow Sweet Spanish Peckham Strain	O.P. variety	"
White Sweet Spanish	" "	"
Yellow Sweet Spanish	" "	"

Station field experiment included 23 cultivars, with six replications, in a randomized block design. A listing of the cultivars and their sources appear in Table 9. Seeds of the above cultivars were sown in single row plots on March 31, 1969. A sample of five seedlings was taken from each plot and several observations were recorded on July 10, 1969. Mean monthly maximum and minimum temperature recorded for the Branch Station during the growing season appear in Table 10.

Table 10. Monthly mean maximum and minimum temperature during experiment 9.

Month	Maximum, ^oF	Minimum, ^oF
April	73.2	37.8
May	79.5	45.7
June	85.1	51.1
July	95.1	60.2
August	94.6	58.7

Tables in the text are given in Arabic numerals, those in the Appendix are given in Roman numerals.

RESULTS AND DISCUSSION

1. Diagnostic symptoms of bulb initation.

1.1. Base/neck ratio.

The most obvious symptom of bulb initiation is the thickening of the basal portion of the plant. In order to use this as a criterion of bulb initiation, the ratio of plant base diameter to neck diameter is calculated. The resulting ratio is referred to in this study as the base/neck ratio. Since scale leaves, rather than foliage leaves, are produced following bulb initiation, comparisons were made between base/neck ratios and number of scales produced within the same plants.

Problems in selecting the base/neck ratio above which bulbing is assumed to have taken place were discussed (page 8). Results shown in Tables i and ii led to the selection of 2.0 as the critical ratio. In Table ii, the mean base/neck ratios of all plants without scales were lower than 2.0. The three samples in which plants contained one scale each, had base/neck ratios ranging from 1.90 to 2.20. Samples in which plants contained more than one scale had base/neck ratios ranging from 2.41 to 2.48. Table i does not have a separate category of plants with one scale each, although the plants sampled are those in which bulbing had just begun. The mean base/neck ratio of plants with no scales on July 3 was 1.58, while the ratio of plants with scales on the same date was 2.51.

Assuming that a base/neck ratio of 2.0 signals bulb initiation, a comparison between base/neck ratios and scale leaf formation was made. Randomly selected plant samples from Experiments 1 (11 cultivars), 2 (10 cultivars), 3 (7 cultivars) and 4 (16 cultivars) were classified into four groups. The four groups and their significance are:

1. Plants without scales and with base/neck ratio exceeding 2.0. These are plants with base/neck ratio indicating bulbing before scales were produced.
2. Plants with scales and with base/neck ratios less than 2.0. These were plants in which scales were produced before the base/neck ratio indicated bulbing.
3. Plants with scales and with base/neck ratio exceeding 2.0. These are plants indicating bulb initiation by both methods, and it cannot be determined which occurred first.
4. Plants without scales and with bulbing ratio less than 2.0. Bulbing had not occurred according to either criterion. This group is included only to show degree of bulbing that occurred in each sample.

The results of comparing base/neck ratios with scale formation are shown in Table iii and summarized in Table 11. Among all plants

Table 11. Base/neck (B/N) ratios and scale formation compared as bulb initiation signals in greenhouse and field grown plants.

			Number of plants					Percent of		
Year	Location	Experiment	B/N $\geq$ 2 (no scales) (1)	Scales (B/N<2) (2)	Scales (B/N>2) (3)	No scales (B/N<2) (4)	Total	(1) to total of (1), (2), & (3)	(2) to total of (1), (2), & (3)	(3) to total of (1), (2), & (3)
1967	Greenhouse Fort Collins	1	5	32	66	73	176	4.8	31.1	64.1
1967	Greenhouse Fort Collins	2	2	48	63	149	262	1.8	42.5	55.7
	Greenhouse	Means						3.2	37.0	59.7
1968	Field Fort Collins	3	2	2	13	73	90	11.8	11.8	76.4
1969	Field Fort Lupton	5	24	64	91	246	425	13.4	35.7	50.8
	Field	Means						13.3	33.7	53.0
	Field and greenhouse							8.0	35.4	56.6

demonstrating bulbing by either method (Table 11), 35.4 percent were in group 2, having produced scales but having base/neck ratios of less than 2.0. Only eight percent of the plants were in group 1, with base/neck ratios greater than 2.0 but with no scales. Results indicate that base/neck ratios greater than 2, while accompanying bulbing, do not usually precede scale formation.

A difference between greenhouse and field grown plants is also presented in Table 11. Among greenhouse grown plants, the mean percentage of plants showing bulb initiation first by a base/neck ratio of 2.0 or greater was 3.2. The percentage of field grown plants in this same group was 13.3.

1.2. Mean leaf ratios of entire seedlings.

The inability to assign a base/neck ratio at which scales were formed necessitated the search for another procedure. The Heath and Hollies (1965) method for determining the degree of bulbing was adopted. Each leaf on a given plant is assigned a number and the ratio means are calculated for corresponding leaves on all plants sampled. Charts are then constructed, as in Figures 1 and 2. The assumption is that bulbing has occurred when the mean ratio for a given leaf is lower than 1.

This method was applied to leaf ratios of successive leaves on different aged plants of the variety 'White Portugal' and the inbred 'B 2190 B', which were field grown at Fort Collins in 1968.

Two methods of counting leaves were used. In the first, leaves were counted outwardly, including all leaves and leaf initials longer than one mm. In the second, leaves were numbered inwardly and outwardly from the youngest visible leaf.

Ratios of 'White Portugal' are plotted in Figure 1. Mean numbers of scales per plant found each week are shown in Table iv. They are 0.33 when the plants were 14 weeks old, 0.50 at 15 weeks, and 1.17 at 16 weeks. In Figure 1, scale formation was indicated only when the youngest visible leaf was used as the reference point, and then only at 15 weeks and at 17 weeks. Mean ratios of the youngest leaf initials, however, were low at 16 weeks, showing the effect of some scale leaves in lowering the mean. When leaves were counted outwardly from the youngest leaf initials, it is even difficult to detect lower means until 16 weeks.

In inbred 'B 2190 B' (Figure 2), as in 'White Portugal', scale formation was clearly demonstrated only when the youngest visible leaf was used as the reference point. This did not occur until the age of 17 weeks, although a mean of 0.83 scales per plant were observed at 15 weeks and 1.83 scales per plant were found at 16 weeks (Table iv).

In both cultivars, it was noticed that the average leaf ratios of the youngest visible leaves fluctuated from week to week in young plants, then steadily decreased prior to scale formation.

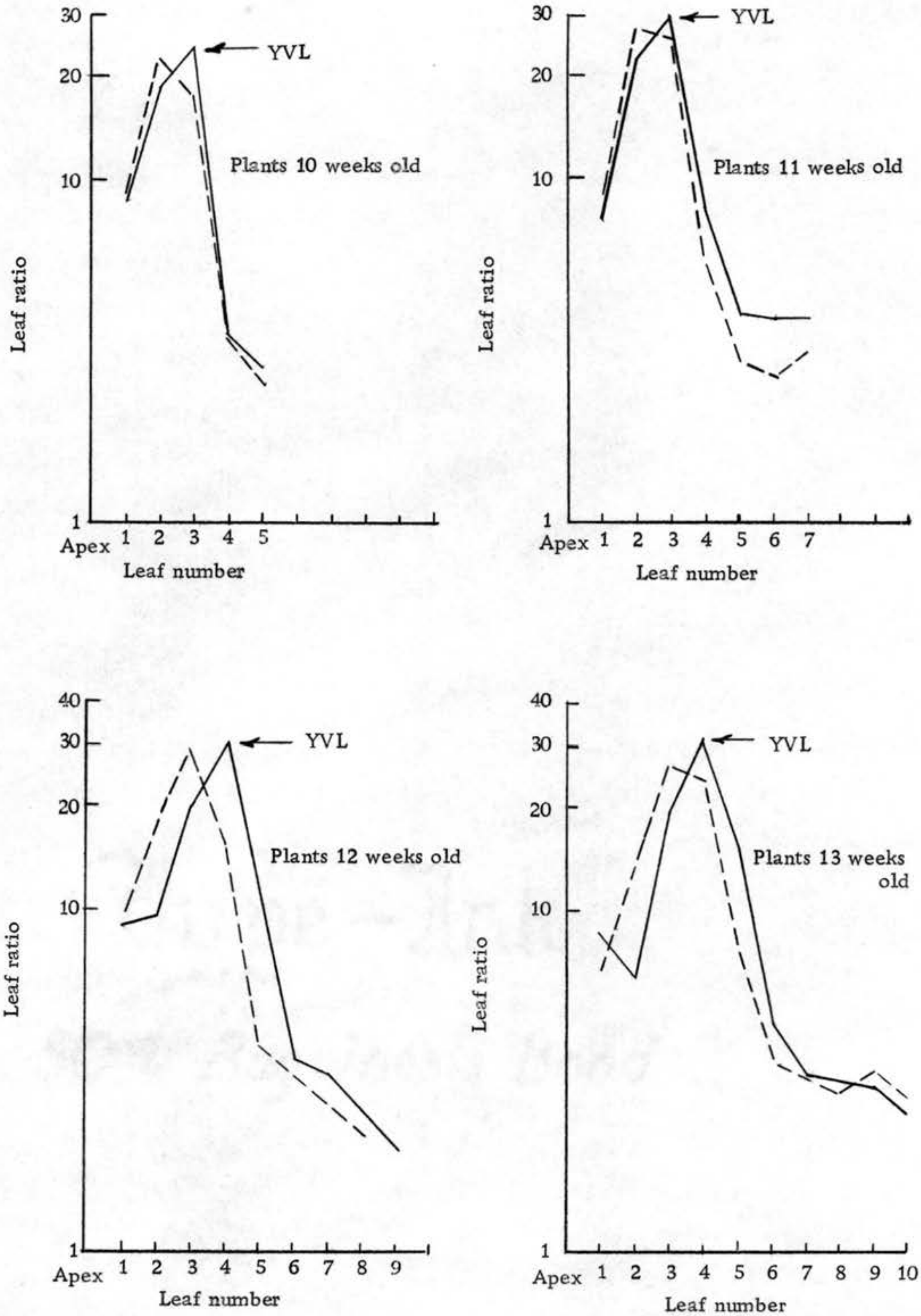


Figure 1. Mean leaf ratios of successive leaves of six 'White Portugal' plants. Leaves numbered outward from innermost leaf initial longer than 1 mm (broken line) and both inward and outward from youngest visible, YVL (solid line). Plants were field grown at Fort Collins, 1968 (Experiment 3).

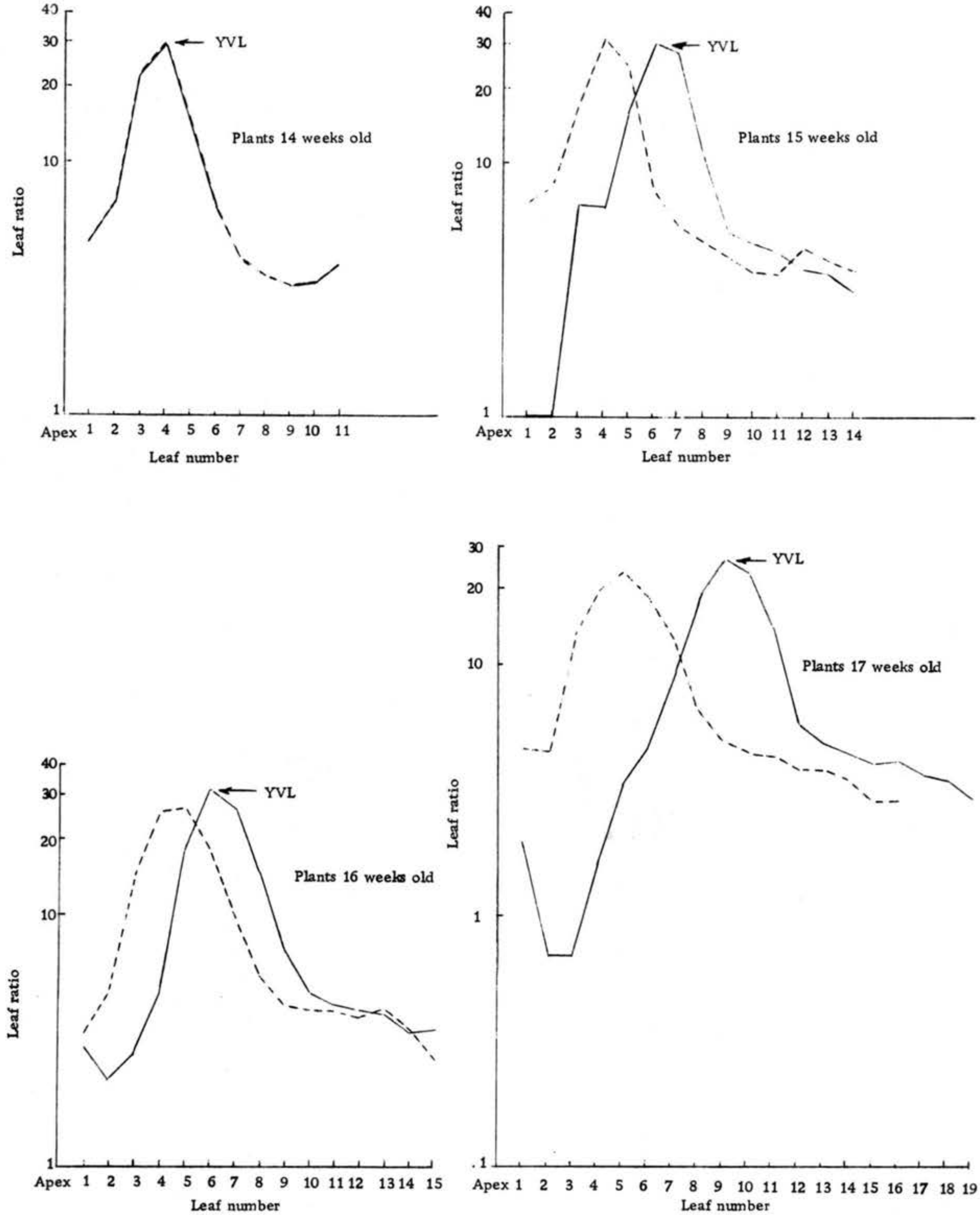


Figure 1 (continued).

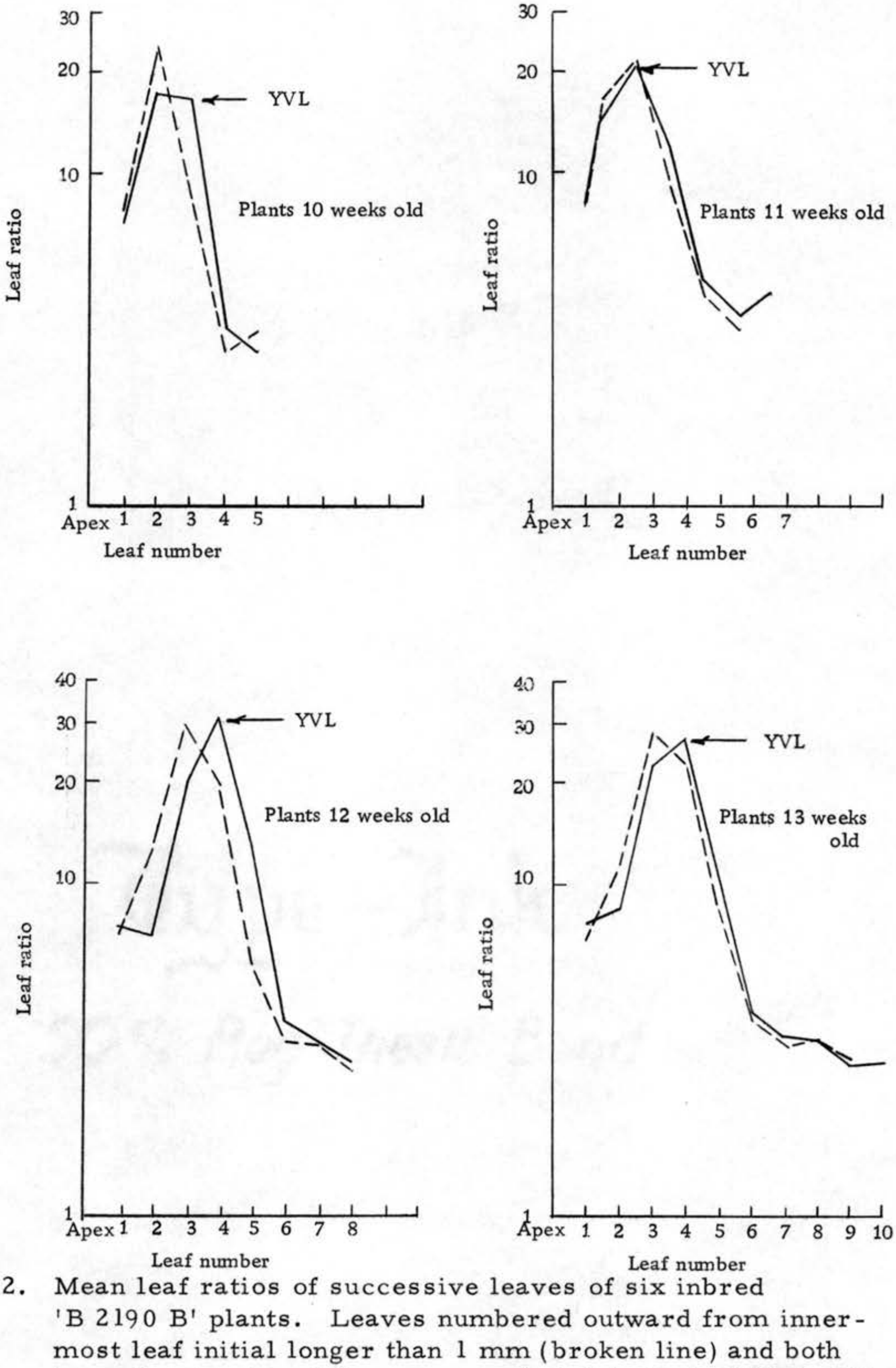


Figure 2. Mean leaf ratios of successive leaves of six inbred 'B 2190 B' plants. Leaves numbered outward from innermost leaf initial longer than 1 mm (broken line) and both inward and outward from youngest visible leaf, YVL (solid line). Plants were field grown at Fort Collins, 1969 (Experiment 3).

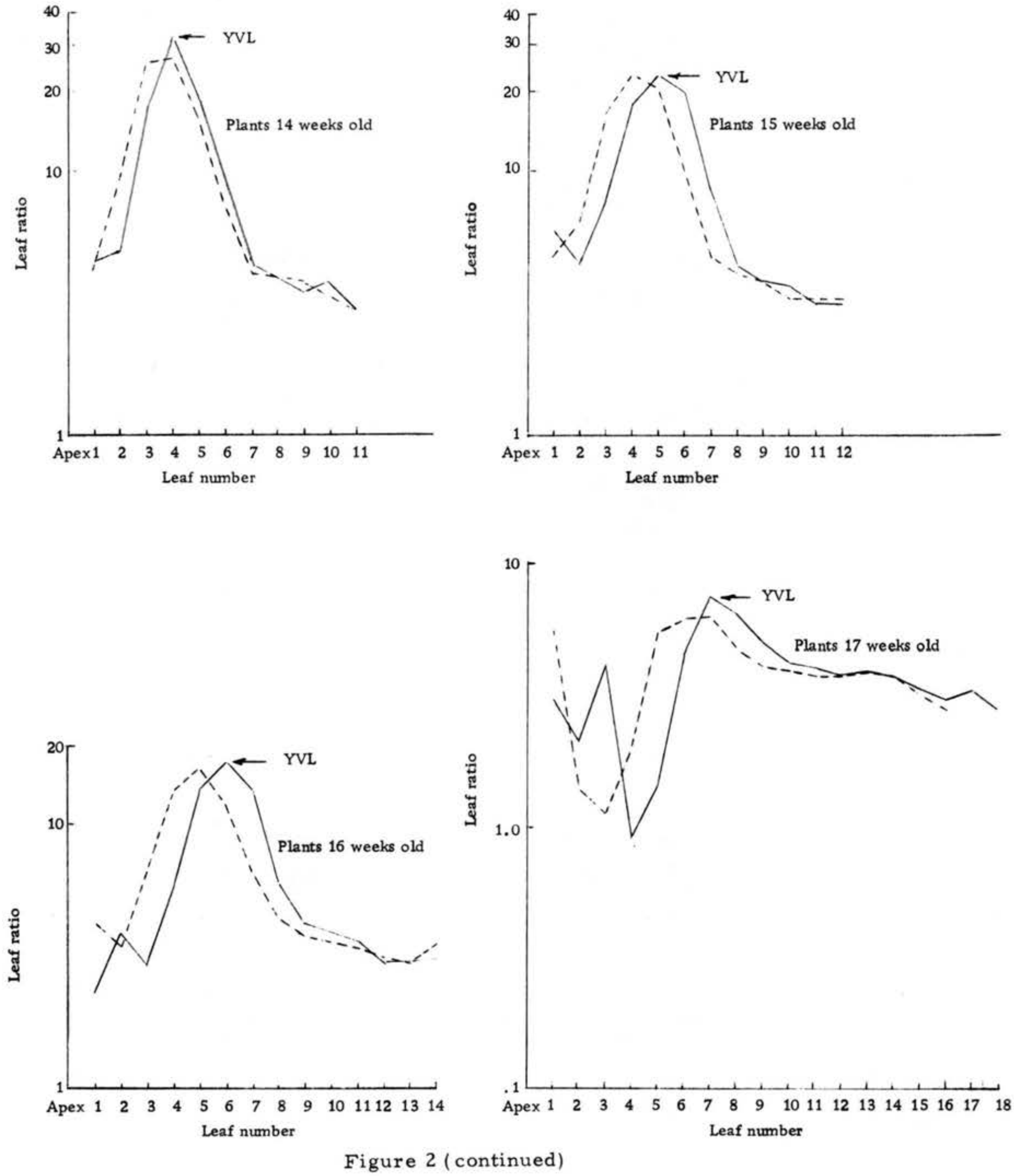


Figure 2 (continued)

Dissection of seedlings to obtain leaf ratios of successive leaves, followed by calculations of means, are tedious and time consuming procedures. Furthermore, neither the time of bulb initiation nor the early development of the bulb could be observed by plotting mean leaf ratios, even using the youngest visible leaf as the reference point.

1.3. Specific leaf ratios.

1.3.1. Maximum and youngest visible leaf ratios.

Youngest visible leaf ratios are those of the youngest visible leaves on each seedling. These same youngest visible leaves were observed in most cases to have the maximum ratios of all leaves on a given plant. When the maximum ratio did not occur on the youngest visible leaf, it nearly always occurred on the leaf immediately interior to it.

If the maximum leaf ratio (MXLR) usually occurs on the youngest visible leaf, the MXLR and the youngest visible leaf ratio (YVLR) should have similar means when the two ratios are obtained for several plants. The similarity is shown in Figures 3A through 8A. It should be recalled from Figures 1 and 2 that the ratios of leaves varied with position on the plant.

Youngest visible leaves are obviously easier to locate than those with maximum ratios and are thus more convenient to use. The significance of these ratios, however, will be more appreciated in later sections.

1.3.1.1. Change of means with plant age.

The steady decrease of the mean youngest visible leaf ratios at the time of scale formation, suggested their possible use as indicators for bulb initiation. Figure 3 presents means for maximum leaf ratios, youngest visible leaf ratios and number of scales for plants at successive ages. This study was based on plants of the variety 'White Ebenezer', greehnouse grown at Fort Collins in 1967. Mean youngest visible leaf ratio decreased from 9.5 at the age of three weeks to 9.4 at the age of four weeks, when 0.65 scales per plant were found. At the age of five weeks, the mean youngest visible leaf ratio was further decreased to 3.5 and the mean number of scales per plant increased to 2.0.

The relationship between YVLR and scale formation for several weeks preceding bulb initiation can be seen again for 'White Ebenezer' in Figure 4. The plants were field grown at Fort Collins in 1968. Mean YVLRs increased slightly and then became fairly constant until the age of 14 weeks. Mean YVLR was 34.3 at the age of 14 weeks, 22.5 at 15 weeks, and 18.4 at 16 weeks. Scale leaves were first observed at 15 weeks.

A third study of 'White Ebenezer' was made from plants grown at Fort Lupton in 1969 (Figure 5). At the age of 12 weeks, mean

YVLR was 32.0 and decreased to 23.4 at 13 weeks. Scale leaves were first observed at 13 weeks.

Two replications of the inbred 'B 2190 B' were grown in the greenhouse at Fort Collins in 1967, and there was a striking difference between the two replications in time of scale formation. In the first replication (Figure 6A1), mean YVLR was 21.5 at the age of three weeks, 28.0 at four weeks, and 16.0 at five weeks. Scale leaves were first observed (Figure 6B1) at five weeks. In the second replication (Figure 6A2) mean YVLR was 28.0 at three weeks and 6.0 at four weeks. Scale leaves were first observed (Figure 6B2) at four weeks. Thus, while the plants in each replication bulbed at different times, the relationship between scale formation and youngest visible leaf ratio remained similar.

Plants of the inbred 'B 2190 B', field grown at Fort Collins in 1968, showed scale formation (a mean of 0.83) at the age of 15 weeks, as shown in Figure 7B. This was accompanied by a decrease in mean YVLRs from a mean of 23.4 at the age of 14 weeks to 17.4 at the age of 15 weeks. As the decrease in mean YVLRs continued, mean number of scales continued to increase. When this same inbred was field grown at Fort Lupton in 1969, scale formation also began at the age of 15 weeks, as shown in Figure 8B. A decrease in mean YVLR preceded that event, Figure 8A. Means of the YVLRs were 28.4, 22.8 and 19.8 for ages 12, 13 and 14 weeks, respectively.

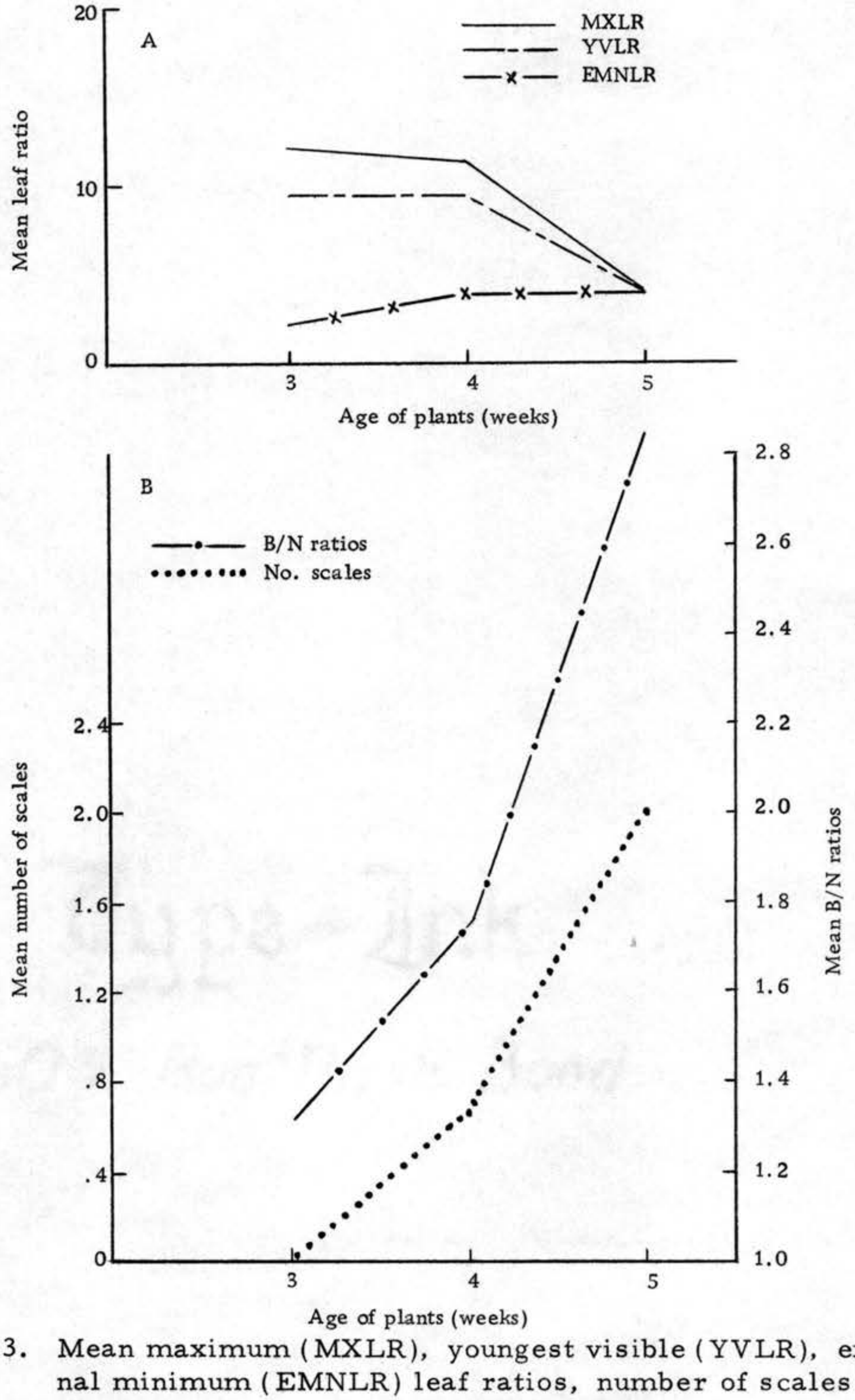
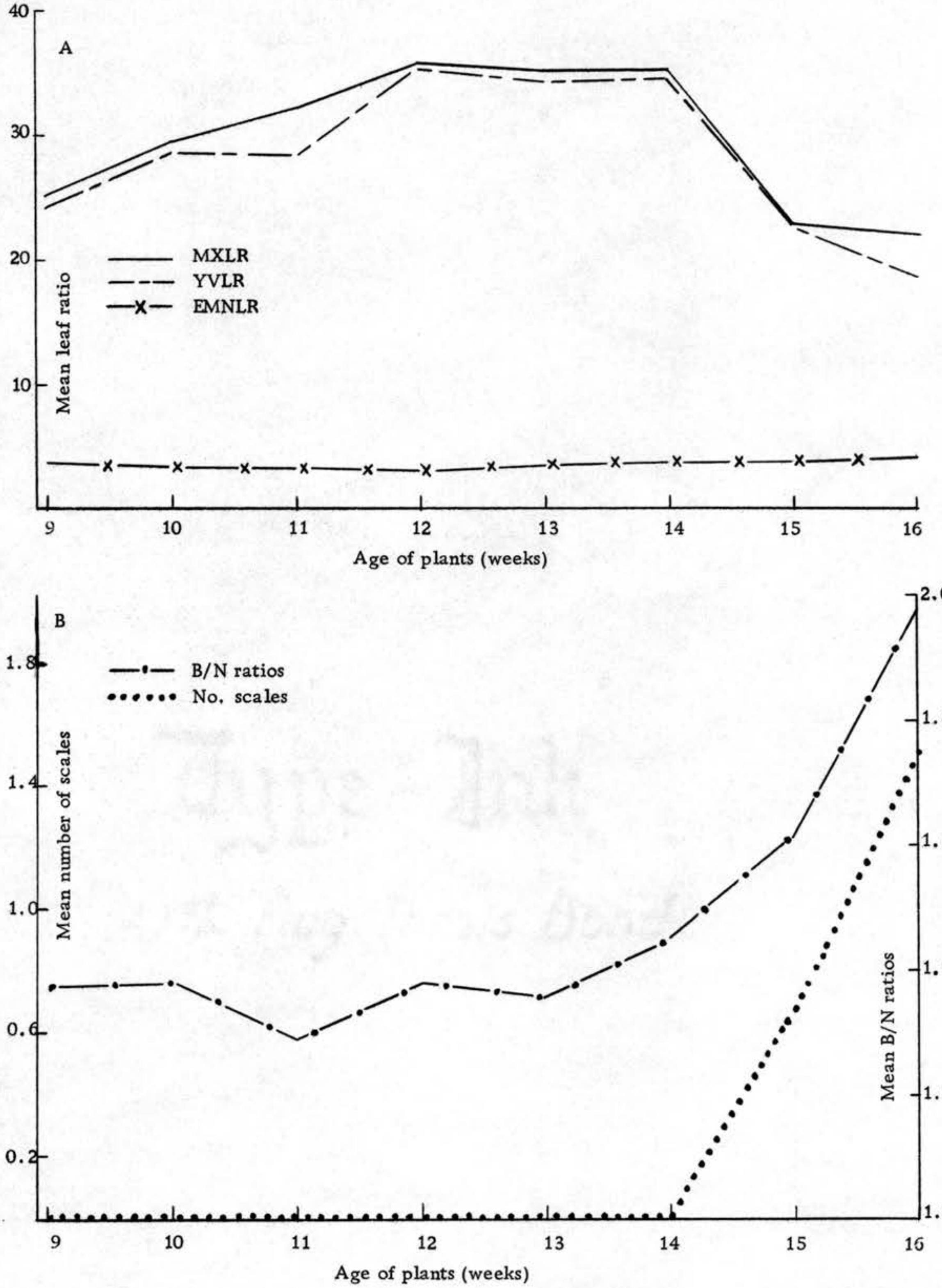


Figure 3. Mean maximum (MXLR), youngest visible (YVLR), external minimum (EMNLR) leaf ratios, number of scales and base/neck (B/N) ratios of six 'White Ebenezer' plants. Plants were greenhouse grown at Fort Collins, 1967 (Experiment 2).

Figure 4. Mean maximum (MXLR), youngest visible (YVLR), external minimum (EMNLR) leaf ratios, number of scales and base/neck (B/N) ratios of six 'White Ebenezer' plants. Plants were field grown at Fort Collins, 1968 (Experiment 3).


A
MXLR
YVLR
EMNLR
Mean leaf ratio
40
30
20
10
9
10
11
12
13
14
15
16
Age of plants (weeks)
B
B/N ratios
No. scales
Mean number of scales
1.8
1.4
1.0
0.6
0.2
Mean B/N ratios
2.0
1.8
1.6
1.4
1.2
1.0
9
10
11
12
13
14
15
16
Age of plants (weeks)

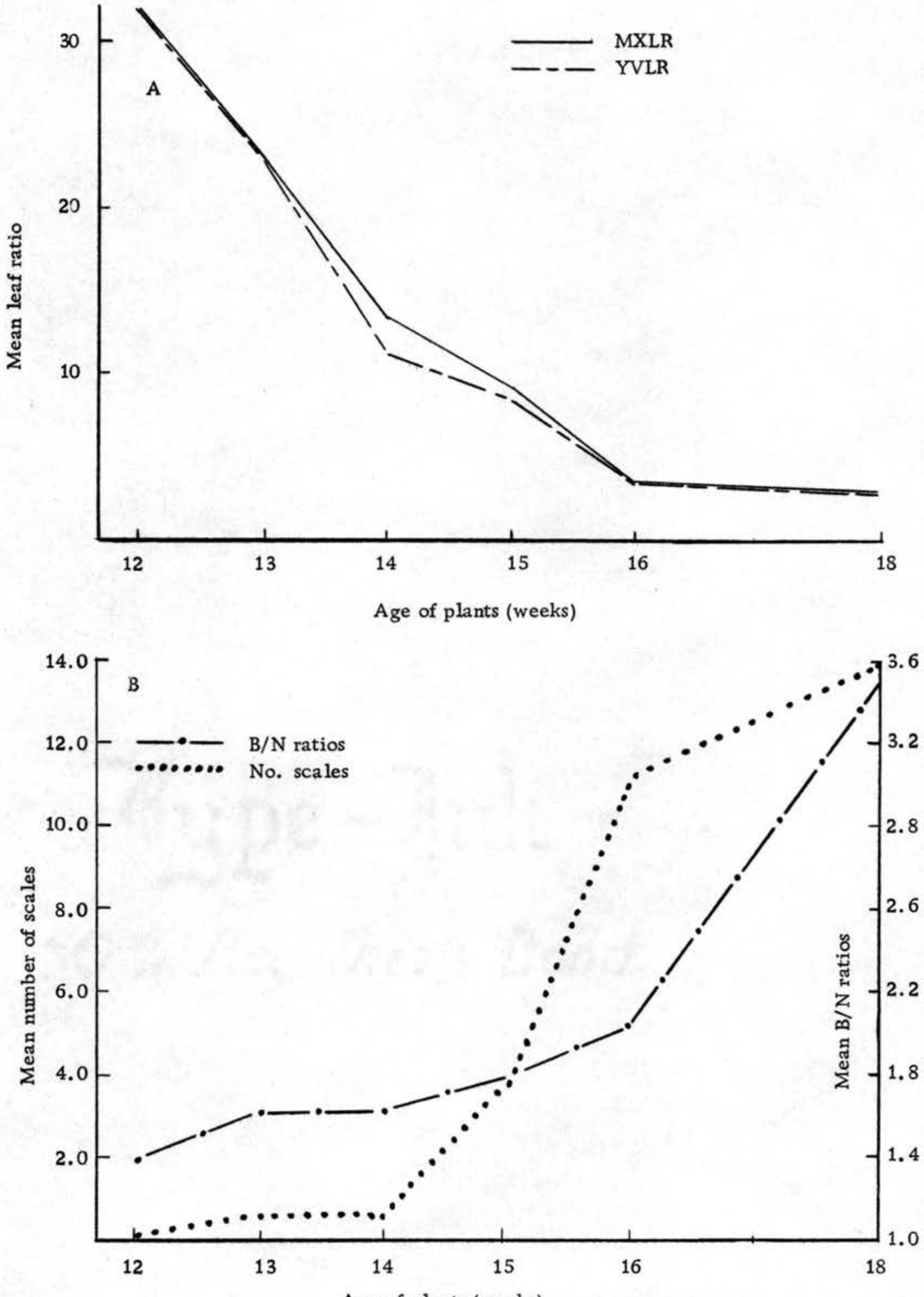


Figure 5. Mean maximum (MXLR), youngest visible (YVLR) leaf ratios, number of scales and base/neck (B/N) ratios of five 'White Ebenezer' plants. Plants were field grown at Fort Lupton, 1969 (Experiment 5).

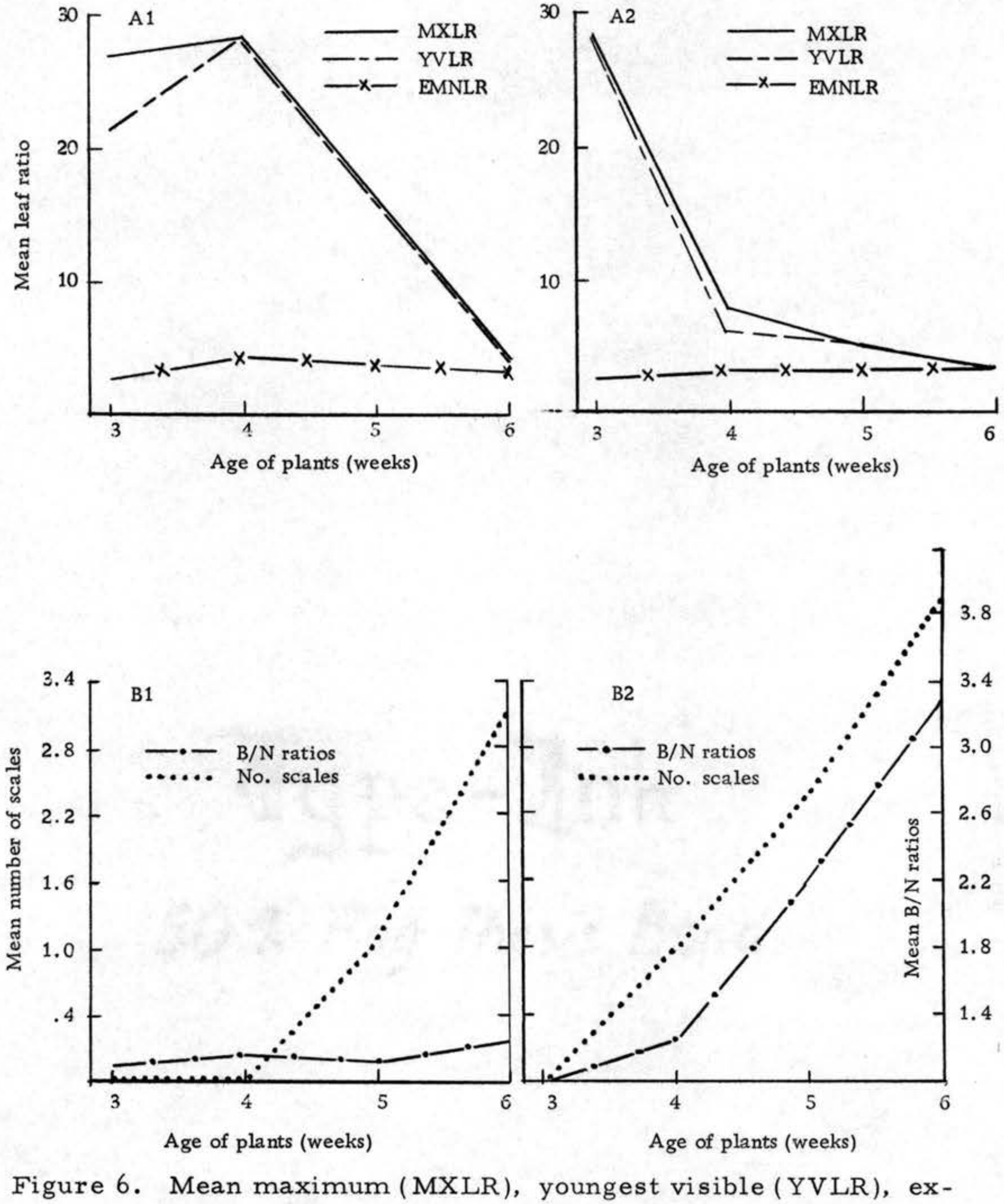


Figure 6. Mean maximum (MXLR), youngest visible (YVLR), external minimum (EMNLR) leaf ratios, number of scales and base/neck (B/N) ratios of three inbred 'B 2190 B' plants. Plants were greenhouse grown at Fort Collins, 1967 (Experiment 1).

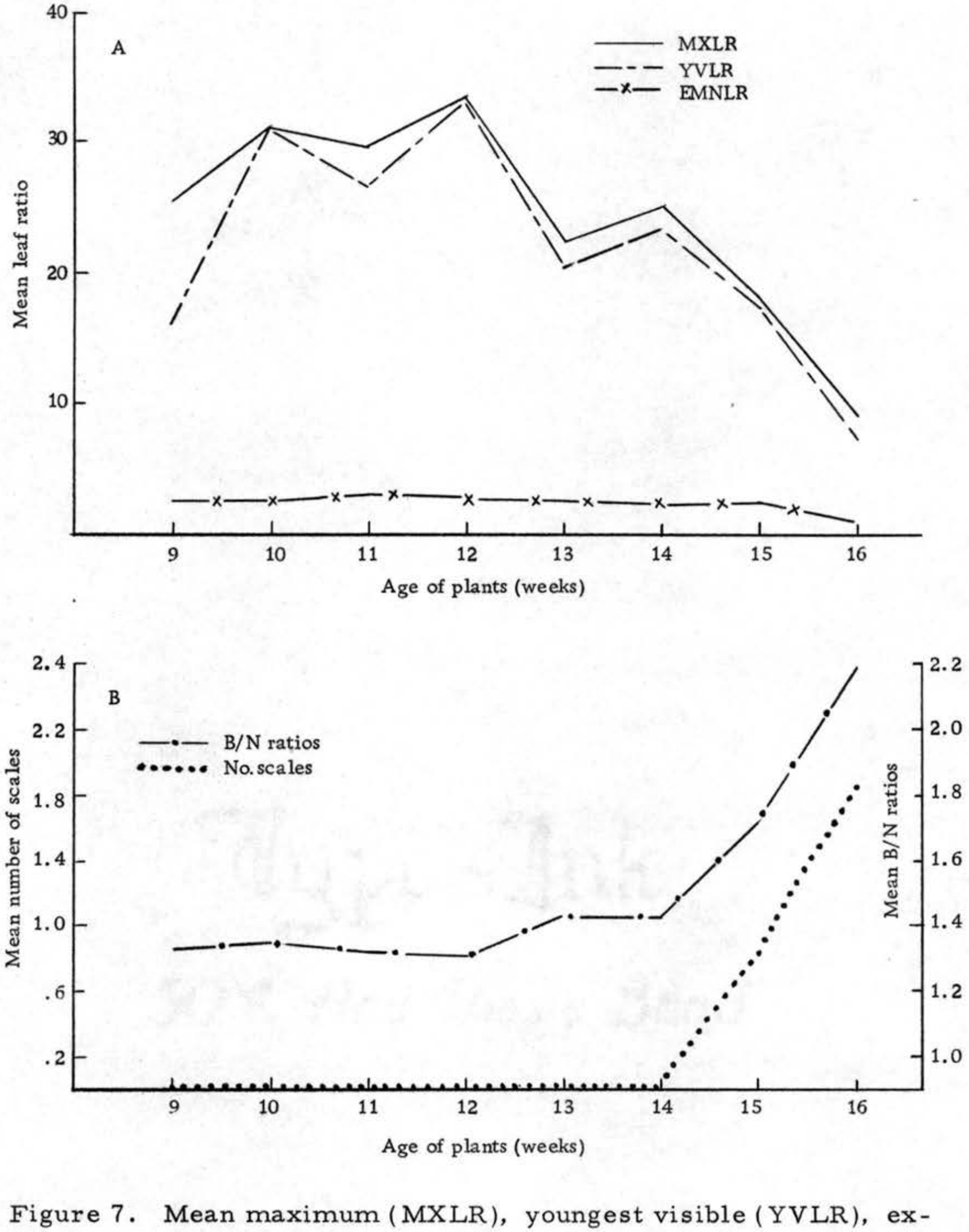


Figure 7. Mean maximum (MXLR), youngest visible (YVLR), external minimum (EMNLR) leaf ratios, number of scales and base/neck (B/N) ratios of six inbred 'B 2190 B' plants. Plants were field grown at Fort Collins, 1968 (Experiment 3).

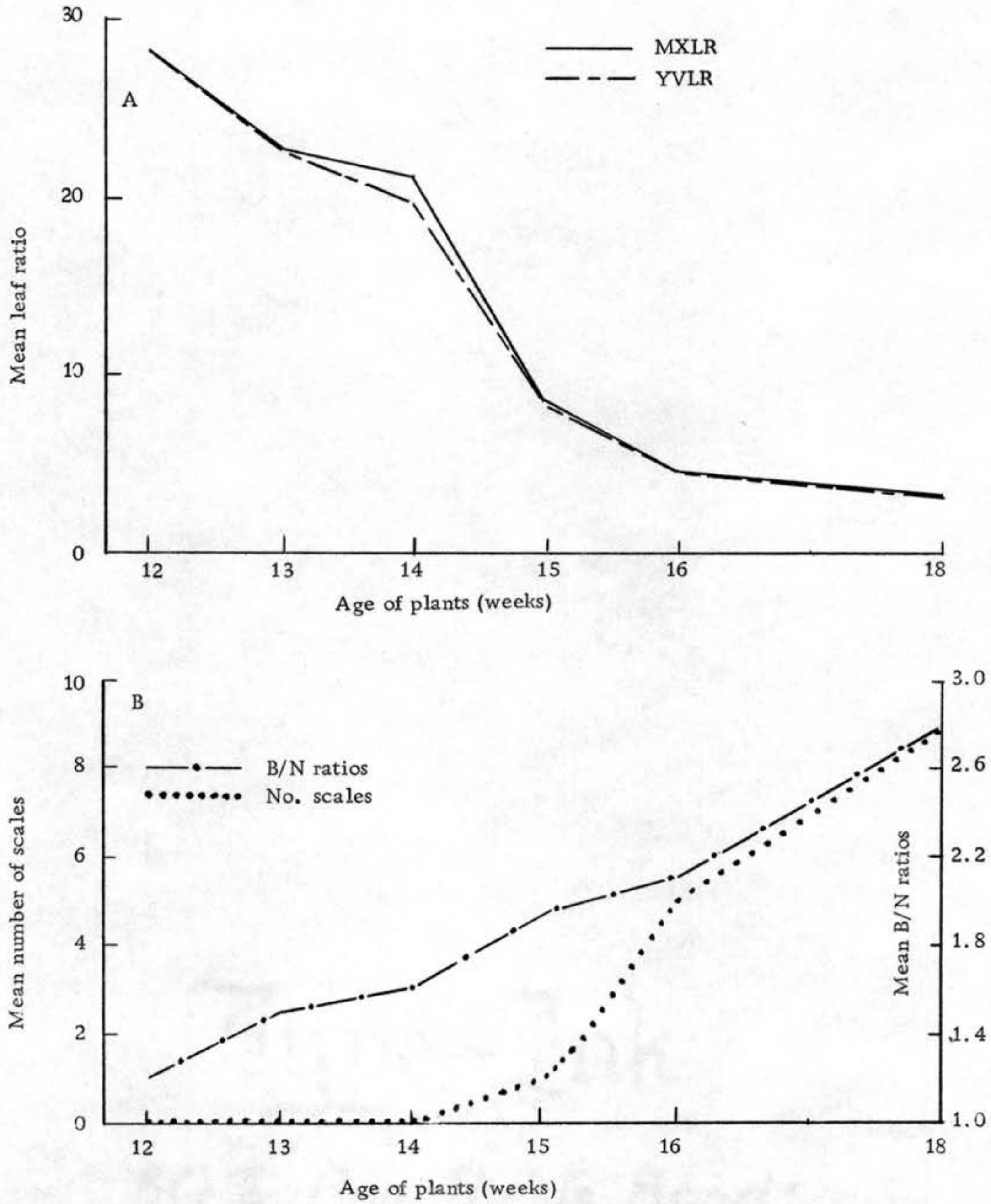


Figure 8. Mean maximum (MXLR), youngest visible (YVLR) leaf ratios, number of scales and base/neck (B/N) ratios of 20 inbred 'B 2190 B' plants. Plants were field grown at Fort Lupton, 1969 (Experiment 5).

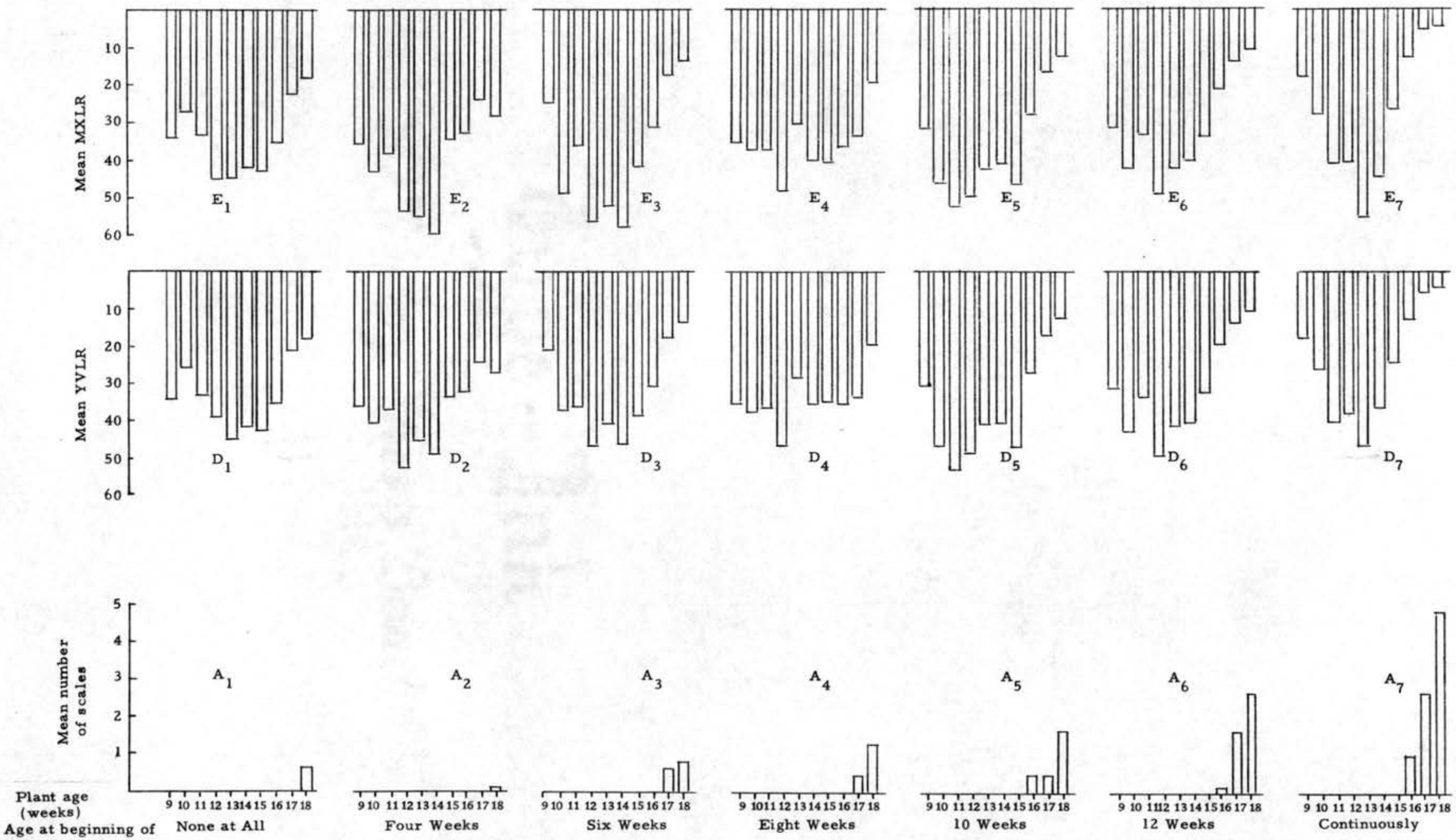


Figure 11. Leaf ratios compared with scale number as bulb initiation symptoms from night interruption study (Experiment 6). Data presented are mean values from six plants of hybrid 'B 2190 A x Colorado 6'.

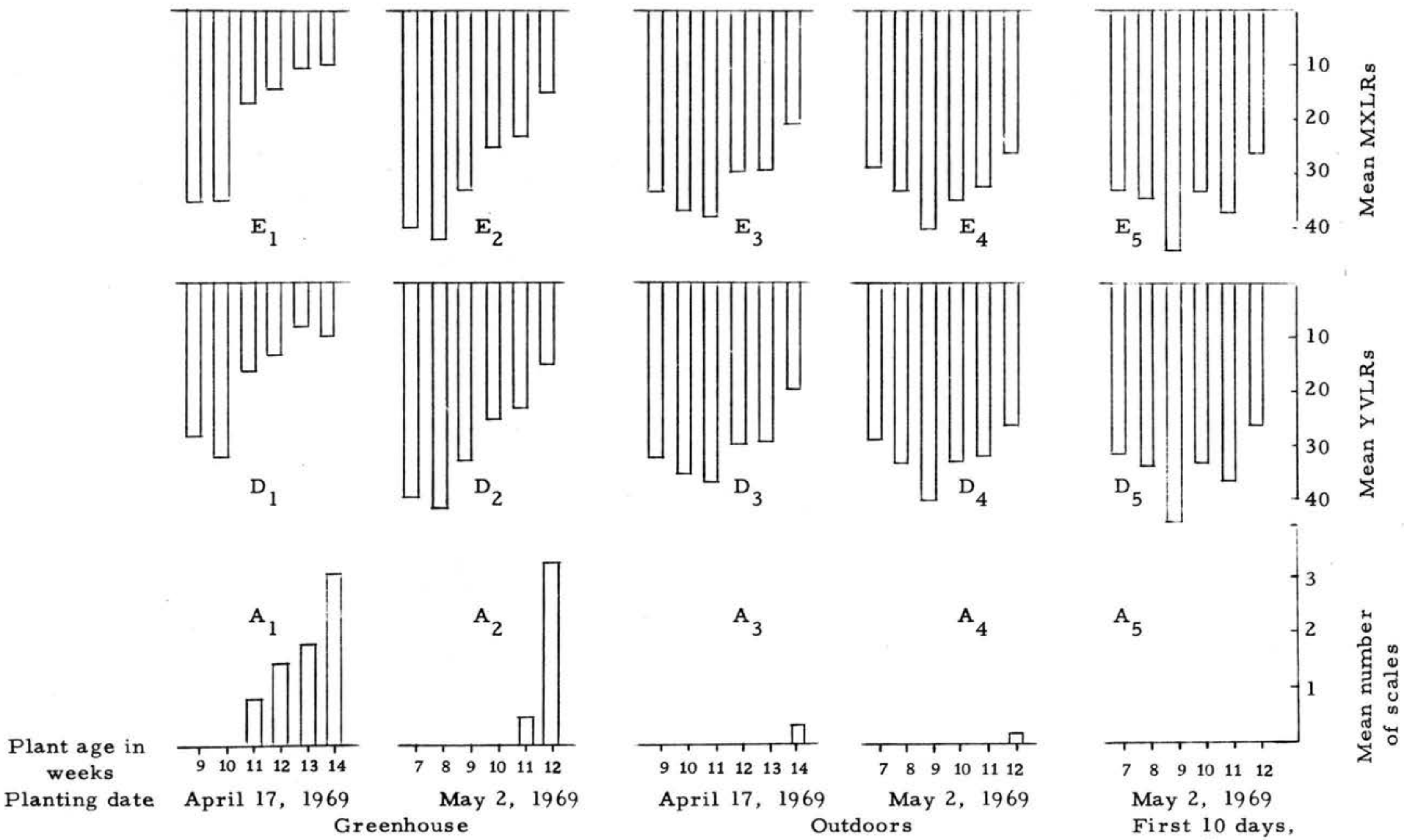


Figure 12. Leaf ratios compared with scale number as bulb initiation symptoms from temperature study (Experiment 7). Data presented are mean values from six plants of hybrid 'B 2190 A x Colorado 6'.

Examination of mean values of the YVLRs, in Figures 11 and 12 and Tables iv, v, and vi, further indicates that a decrease in those means precedes or accompanies scale formation. Two consecutive decreases in mean YVLRs are identified by asterisks in all tables referred to. With the exception of the variety 'White Portugal', in Table iv, all varieties showed scale formation at the same time as, or preceded by, two consecutive weekly decreases in mean YVLR. Tables v and vi present data on the hybrid 'B 2190 A x Colorado 6', grown under different environmental conditions. In all cases in which scale formation was found, two consecutive decreases in mean YVLR signalled scale formation. In all but two cases, one in each table, the second decrease preceded scale formation by one or two weeks; and in both of these exceptions the first of the two decreases occurred at the same sampling date as the first occurrence of scales. There were also two cases in which no scales were found. In one of these there was also no two week series of ratio decreases. In the other one, scale formation did not occur in two weeks following the decrease in ratios. This latter case, involving night interruption at the age of four weeks, may be one of reversal of the bulb initiation process. After a decrease in ratios for three consecutive weeks, there was an increase from 23.4 to 26.7.

Formation of scales in some varieties listed Table ix occurred at the first sampling date, i.e., when plants were three weeks old. Because of this, a detailed discussion of this table is not presented. A cursory examination of the results, however, indicates the same relationship between scale formation and change in mean YVLR.

In summary, weekly samples from most of the cultivars examined showed that scale formation appeared at the same sampling date or one or two weeks following a decrease in the mean YVLR. The decrease in mean ratio was usually followed by another decrease the following week. These results occurred under a wide range of environmental conditions and regardless of the age at which bulbing was initiated. The sampling method used was adopted to determine the feasibility of using the ratio to detect bulb initiation. More precise sampling would, of course, be necessary for more immediate information on ratio changes.

1.3.1.2. Mean youngest visible leaf ratio.

A summary of mean youngest visible leaf ratios at the time of scale formation is given in Table 12 for all cultivars studied. It is obvious that no specific YVLR signals the initiation of scale formation. It is also obvious that a given variety grown under different conditions produced different ratios at the time of scale formation. Examples of the wide range of values are found among the cultivars grown in the greenhouse at Fort Collins in 1967, in the field at Fort Collins in 1968 and in the field at Fort Lupton in 1969. The ranges in mean

YVLR at the time of scale formation were 8.2 to 18.5, 13.3 to 30.2, and 4.6 to 23.4 for all cultivars grown under these three sets of conditions. The variety 'White Ebenezer' had a mean YVLR of 9.4 at the time of scale formation when grown in the greenhouse at Fort Collins in 1967. Field grown plants from Fort Collins (1968) and Fort Lupton (1969) produced mean YVLRs of 22.5 and 23.4. Plants of the inbred 'B 2190 B' showed mean YVLRs at the time of scale formation of 16.1, 17.4 and 8.3, when greenhouse grown at Fort Collins in 1967, field grown at Fort Collins in 1968 and field grown at Fort Lupton in 1969, respectively. In this inbred, the greenhouse sample and one field sample were more similar than the two field grown samples. No varietal or environmental classification appeared evident.

The mean YVLR at which scales were formed was found to vary greatly. Great differences were found among cultivars, among different environmental conditions, and even within one cultivar under similar environmental conditions. A drop in ratios for two successive weeks clearly signalled bulb initiation, but obviously no absolute mean values of YVLRs to diagnose initiation of scale formation can be obtained.

1.3.1.3. Correlations between internal minimum leaf ratios and individual plant maximum and youngest visible leaf ratios.

Table 12. Mean youngest visible leaf ratios (YVLR) at time of scale formation in 29 cultivars grown in 1967, 1968 and 1969.

Cultivar	Mean YVLR at time of scale formation: Fort Collins Greenhouse, 1967		Fort Collins Field, 1968		Fort Lupton Field, 1969	
	Mean ratio[1]	Age of plants[3]	Mean ratio[1]	Age of plants[3]	Mean ratio[2]	Age of plants[3]
1. Australian Brown	8.2	4				
2. Yellow Ebenezer	10.4	4				
3. Southport White Globe	8.5	4				
4. White Lisbon	10.6	5				
5. White Ebenezer	9.4	4	22.5	15	23.4	13
6. Crystal White Wax	8.6	4				
7. 8875 B	17.7	4				
8. 1288 A	11.9	4				
9. 1288 A x 8875 B	13.6	4				
10. 2997 A	15.8	4				
11. 2997 A x Colorado 6	13.3	5				
12. B 2190 B	16.1	4	17.4	15	8.3*	15
13. 1900 A	9.7	4				
14. 1900 A x B 2190 B	17.3	4				
15. 1900 A x Colorado 6	18.5	5				
16. Colorado 6	9.0	4				
17. P 54-306 B			13.3	16	6.9	16
18. White Sweet Spanish			15.3	16	14.1	16
19. Ia 42 B			22.3	14	19.0	14
20. Ia 2997 B					9.8	16

Table 12. (cont.)

Cultivar	Mean YVLR at time of scale formation					
	Fort Collins Greenhouse, 1967		Fort Collins Field, 1968		Fort Lupton Field, 1969	
	Mean ratio[1]	Age of plants[3]	Mean ratio[1]	Age of plants[3]	Mean ratio[2]	Age of plants[3]
21. B 5546 B					6.1	15
22. B 2108 B					6.4	15
23. B. C. (2264 A x Colorado 6) x Colorado 6					11.9*	15
24. Ia 42 A x Colorado 6					12.3*	15
25. 2108 A x Ia 2997 B					4.6	15
26. White Portugal			30.2	14		
27. B 12115-2			22.8	15		
28. B 2215					8.3	15
29. 1900 B					11.7	15

1 Means of six plants.
2 " " five plants.
* " " 20 plants.
3 In weeks.

It has been established that scales are leaves with ratios less than 1.0. The most reduced leaf ratio in the plant is the minimum leaf ratio and, since the first scale is formed from one of the leaf initials (Figures 1 and 2), the internal minimum leaf ratio (IMNLR) is pertinent to this discussion.

To compare effectiveness of YVLRs and maximum leaf ratios (MXLR) in indicating IMNLR reduction, the correlations in Table 13 were calculated. When the correlations were first calculated, they did not show the expected results, but transformation of all values to their natural logarithms (ln) yielded significant results, indicating linear relationships.

Values of correlation coefficients between ln IMNLRs and ln MXLRs were all highly significant and positive, ranging from 0.690 and 0.904. These correlation coefficients were consistently higher than those obtained for the same plants between ln IMNLRs and ln YVLRs. Values for the latter, which were all positive and statistically significant, ranged from 0.509 to 0.773. Both sets of correlations were calculated on different types of cultivars, some of which were grown under extremely different environmental conditions. The results indicate that maximum leaf ratios are more effective than youngest visible leaf ratios in predicting changes in internal minimum leaf ratios, and presumably in scale formation.

Regression coefficients, also shown in Table 13, of ln IMNLR on ln MXLR, range from 1.24 to 2.32, with a pooled value of 1.64. Analysis of regression revealed no significant variation among regression coefficients. Plotting of ln internal minimum leaf ratios with ln maximum leaf ratios and with ln youngest visible leaf ratios, along with regression lines are shown in Figures 9 and 10. The examples shown are those listed in Table 13 and two other cases. With the exception of the rare circled points, it is possible to divide the plotted values in Figure 9 into two distinct groups. In the first group are those plants with ln IMNLRs of 0 or less (with scales) and with ln MXLRs ranging from 1.8 to 2.7, with a mean of 2.32 (unconverted value of about 10). The second group included the rest of the plants, which had no scales, i.e., ln IMNLRs greater than 0. These plants had ln MXLRs greater than 2.32, i.e., unconverted leaf ratios greater than 10.

Figure 10, on the other hand, shows that an attempt to separate plants into bulbing and nonbulbing classes on the basis of YVLRs instead of MXLRs would not be as successful.

Table 19 in section 2.5. presents data supporting the use of the maximum leaf ratio. Plants in one of the three treatments produced scales as a result of night interruption, and those in the other two treatments did not produce scales but were exposed to two different photoperiods. Plants were all the same age when examined.

Mean MXLR was 3.1 for plants with scales. Corresponding means were 43.1 for plants exposed to nine hours of photoperiod and 30.4 for plants exposed to natural photoperiod (14 to 13 hours). Although the difference among the three means is statistically significant, the treatment producing scales had a mean MXLR far below 10 and those producing no scales had ratios far exceeding 10.

Further examination of the MXLR as an indicator of scale formation was made with plants of field grown cultivars from Fort Lupton in 1969. MXLRs of individual plants were grouped according to whether or not scales were observed (Table 14). The plants were also classified as to whether or not they developed lateral buds.

All plants of the inbred 'B 2190 B' with scales had MXLRs below 10, and those without scales had MXLRs greater than 10 if there were no lateral buds. Most of the plants with lateral buds had maximum leaf ratios less than 10. Bulb initiation may still have taken place, however, in those plants with lateral buds, no scales, and MXLRs which indicate bulbing. Lateral bud development is a part of the bulbing process in a large number of cultivars, according to Jones and Mann (1963).

The behavior of plants of the variety 'White Ebenezer' and the hybrid 'Ia 42 A x Colorado 6' was similar to that of plants of the inbred 'B 2190 B'. Few plants deviated from this behavior in the latter two cultivars. One plant in each of the latter two cultivars had an MXLR less than 10, yet neither formed scales nor developed lateral buds. These few plants can be assumed to be either undergoing scale or lateral bud formation, or their developed lateral buds were so small that they escaped detection during the fast dissection of plants. 'White Ebenezer' and 'Ia 42 A x Colorado 6' each had a plant which formed scales and developed lateral buds, yet had an MXLR greater than 10. No plausible explanation for the occurrence of such exceptional plants was obtained from these results.

1.3.1.4. Correlations between maximum and youngest visible leaf ratios.

Correlations between MXLRs and YVLRs for plants of several cultivars and several environmental conditions were all highly significant and positive (Table 15). Values of correlation coefficients ranged from 0.782 to 1.000. Number of plants in which the MXLR occurred in either the youngest visible leaf or the one immediately interior to it is also shown in Table 15. In 15 percent of the greenhouse grown plants in 1967 and in 10 percent of the 1968 Fort Collins field grown plants examined, the MXLR occurred in the leaf immediately interior to the youngest visible leaf. The use of the youngest visible leaf is more convenient and less destructive to selected plants which are to be saved by a breeder.

Data presented in section 1.3.1.3. show that MXLRs more accurately predict internal scale formation. A compromise between

Table 13. Regression (b) and Correlation (r) coefficients between ln internal minimum leaf ratio and each of indicated characters for some greenhouse and field grown cultivars, in 1967 and 1968.

			Regression coefficient (b) of IMNLR and		Correlation coefficient (r) between IMNLR and			
Cultivar	Year	Locality	ln MXLR	ln YVLR	ln MXLR	95 percent confidence interval	ln YVLR	ln EMNLR
White Ebenezer	1967	Greenhouse	1.58	1.24	.727**	.58 - .84	.509*	
White Ebenezer	1968	Field	1.40	1.06	.777**	.64 - .86	.661**	
1900 A x B 2190 B	1967	Greenhouse	1.96	1.67	.888**	.84 - .94	.737**	
1900 A x Colorado 6	1967	Greenhouse	1.69	1.28	.904**	.85 - .95	.773**	
White Portugal	1967	Greenhouse	2.32	1.53	.818**	.70 - .88	.539*	-.172[1]
White Portugal	1968	Field	1.42	1.25	.690**	.60 - .83	.650**	-.201[1]

Table 13. (cont.)

Cultivar	Year	Locality	Regression coefficient (b) of IMNLR and: ln MXLR	ln YVLR	Correlation coefficient (r) between IMNLR and: ln MXLR	95 percent confidence interval	ln YVLR	ln EMNLR
B 2190 B	1967	Greenhouse	1.59	1.39	.868**	.76 - .93	.763**	.004[1]
B 2190 B	1968	Field	1.24	.73	.727**	.58 - .84	.517**	.261[1]
F for regression due to $\bar{b}$			471.3**	183.4**				
F for variation among b's			1.96[1]	1.5[1]				
$\bar{b}$			1.64	1.25				

1 statistically non-significant

* " significant

** " highly significant

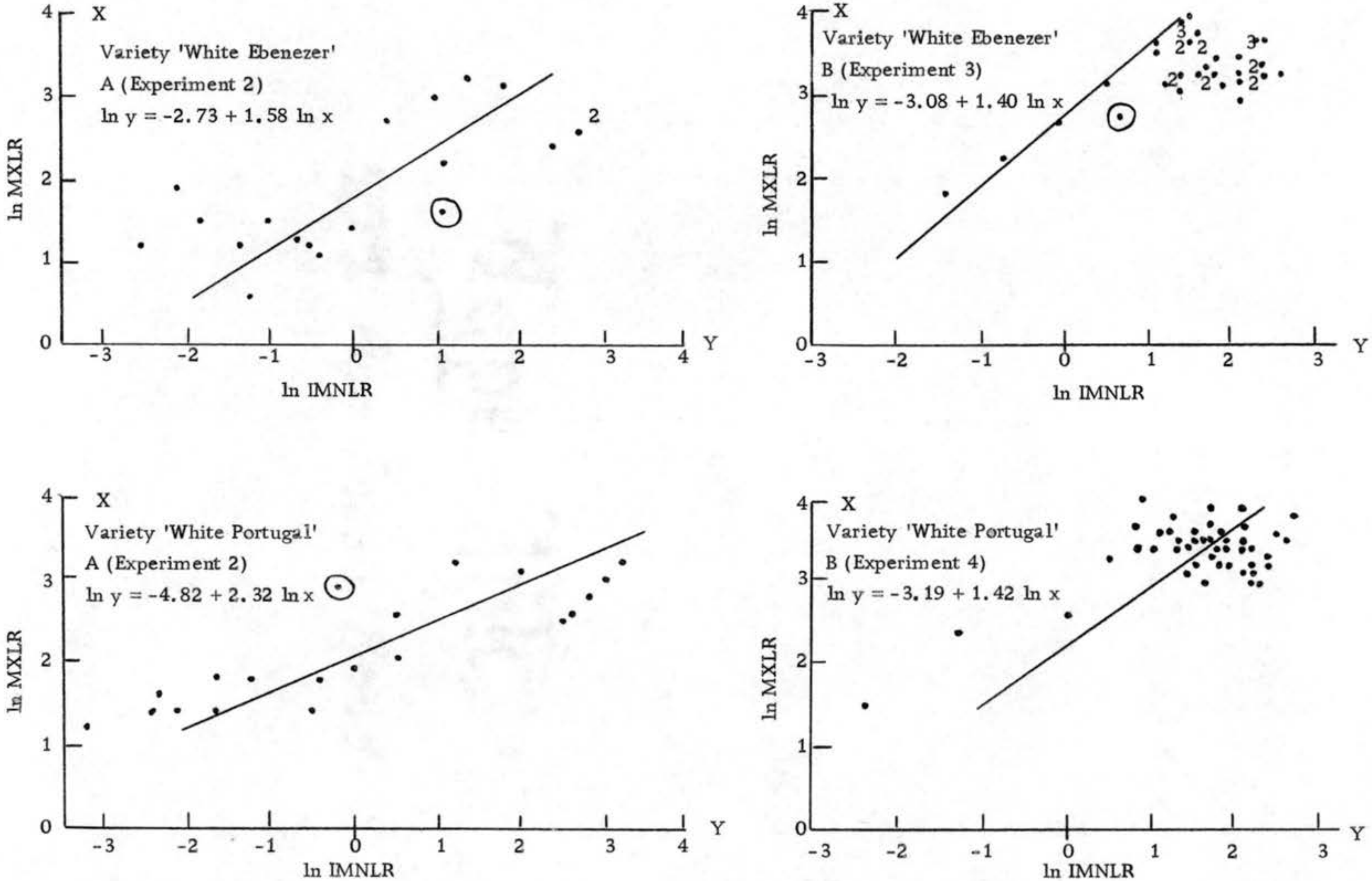


Figure 9. Natural logarithms (ln) of maximum leaf ratios (MXLR) and internal minimum leaf ratios (IMNLR). Data presented are based on individual plants from five cultivars, greenhouse (A) and field (B) grown at Fort Collins.

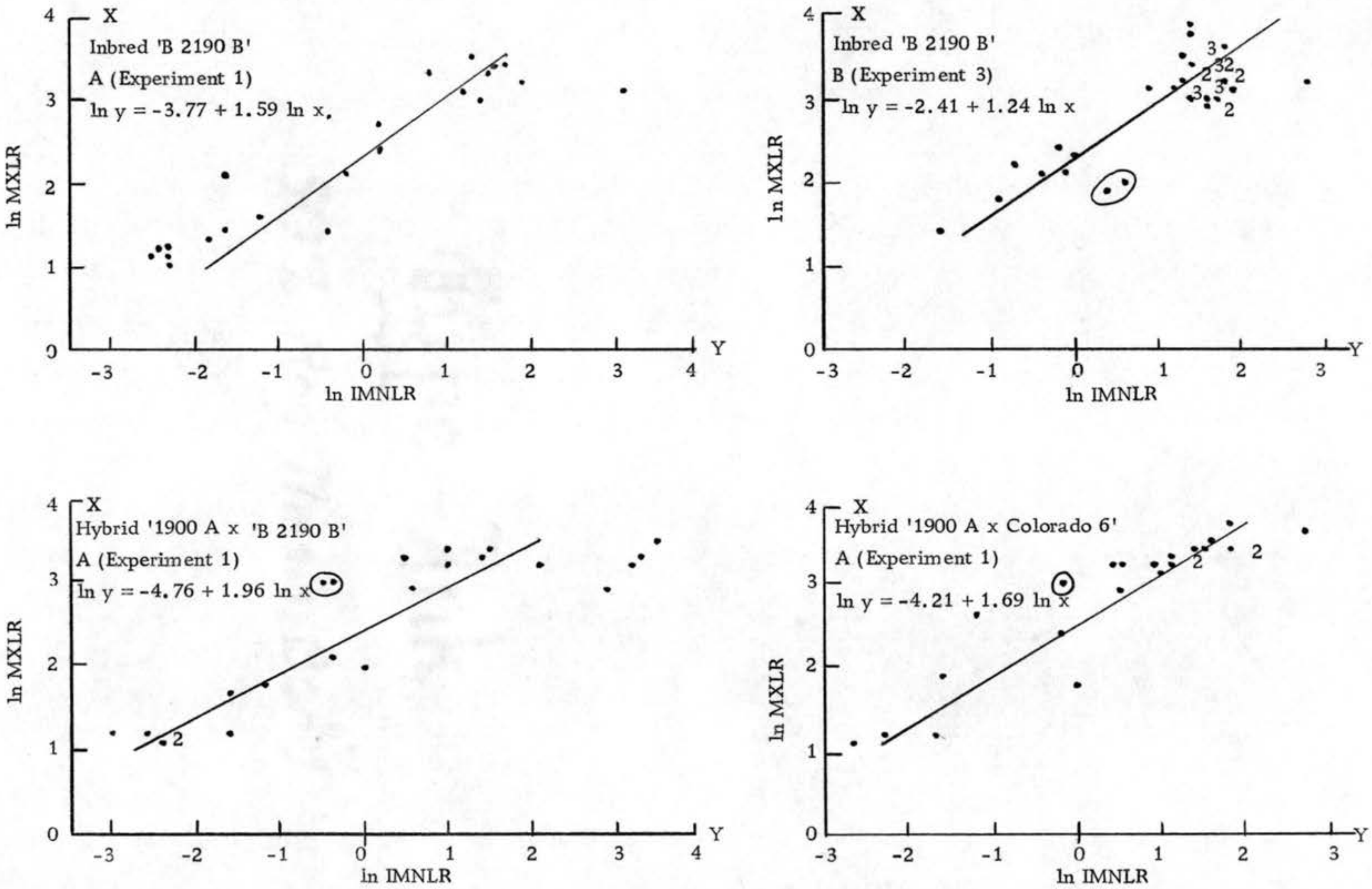


Figure 9 (continued).

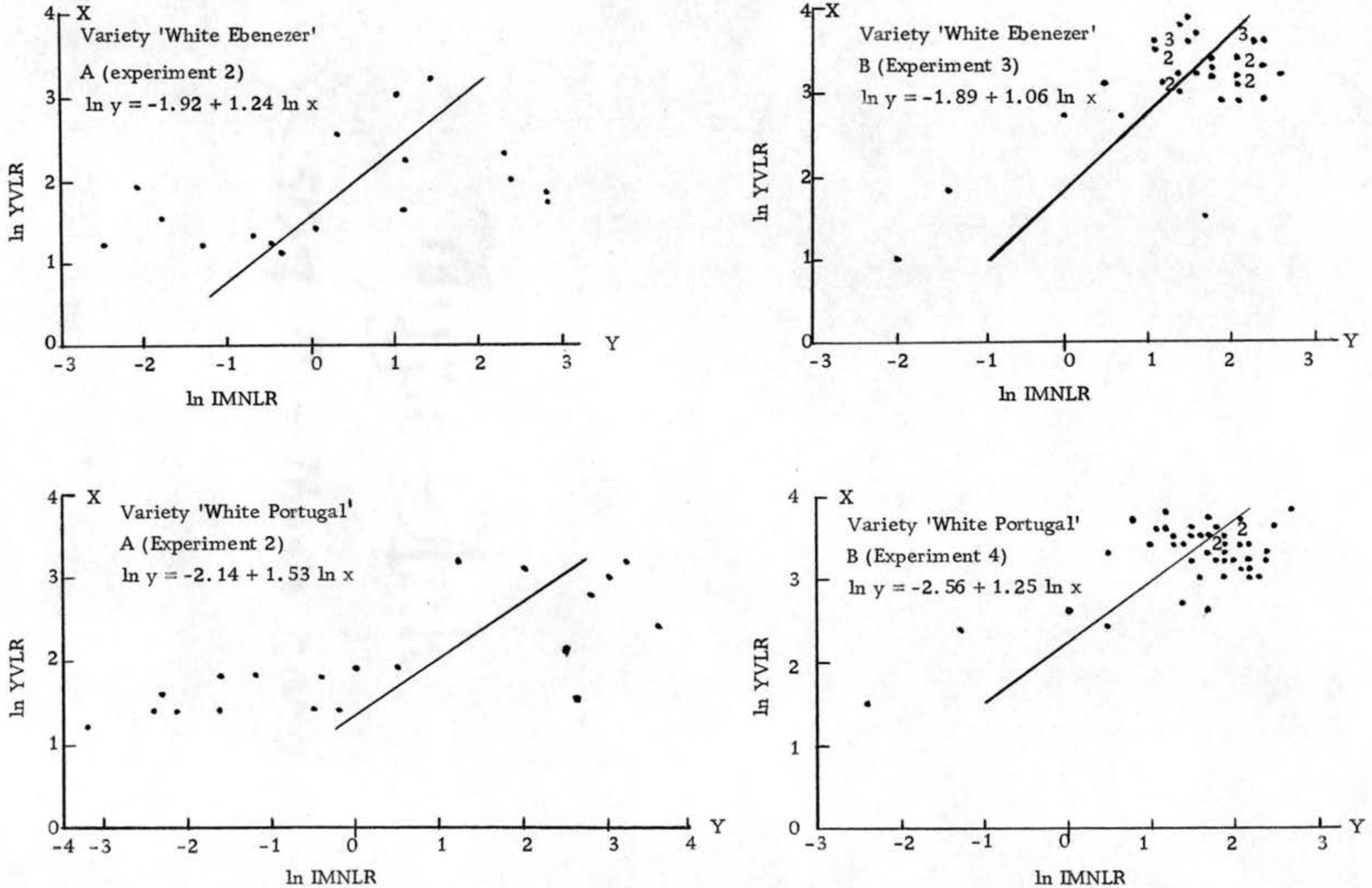


Figure 10. Natural logarithm (ln) of youngest visible leaf ratios (YVLR) and internal minimum leaf ratios (IMNLR). Data presented are based on individual plants from five cultivars, greenhouse (A) and field (B) grown at Fort Collins.

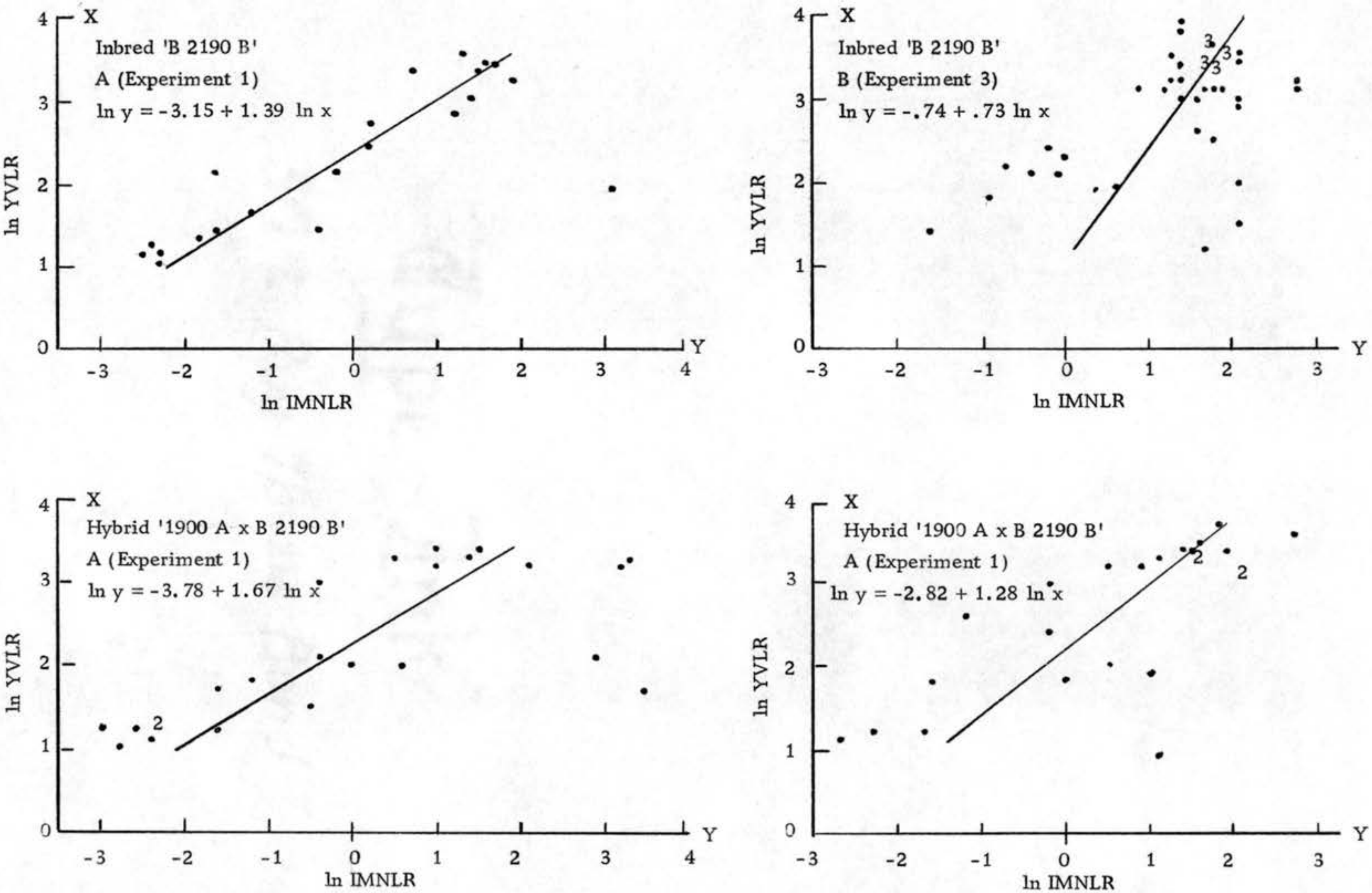


Figure 10 (continued)

Table 14. Maximum leaf ratio (MXLR) of three cultivars, with and without scales and lateral buds. Plants were field grown at Fort Lupton, 1969 (Experiment 5).

Cultivar	Scales	Lateral buds	No. plants with MXLR range of 1-10	11-20	21-30	31-40	41-50
B 2190 B	Absent	Absent	0	11	14	5	0
		Present	7	1	0	0	0
	Present	Absent	9	0	0	0	0
		Present	41	0	0	0	0
White Ebenezer	Absent	Absent	1	1	4	2	0
		Present	0	3	0	2	0
	Present	Absent	1	0	0	0	0
		Present	15	1	0	0	0
Ia 42 A x Colorado 6	Absent	Absent	1	11	10	5	1
		Present	4	9	3	1	0
	Present	Absent	3	0	0	0	0
		Present	38	1	0	0	0

Table 15. Correlation coefficients between maximum (MXLR) and youngest visible leaf (YVLR) ratios among greenhouse and field grown cultivars, Fort Collins, 1967 and 1968 (Experiments 1 and 3). Distribution of MXLR within is also given.

Year	Locality	Cultivar	No. of Pairs	r	No. of plants in which MXLR occurs in	
					Youngest visible leaf	Leaf immediately interior to YVL
1967	Fort Collins	8875 B	24	0.942	21	3
	Greenhouse	1288 A	23	0.999	22	1
		1288 A x 8875 B	24	1.000	24	0
		Colorado 761	24	0.782	17	7
		2997 A	24	0.959	23	1
		2997 A x Colorado 761	24	0.827	19	5
		2190 B	24	0.950	21	3
		1900 A	24	0.879	17	7
		1900 A x 2190 B	24	0.824	21	3
		1900 A x Colorado 6	24	0.883	21	3
		Colorado 6	24	0.892	17	7
Percentage from total					85	15

Table 15. (cont.)

Year	Locality	Cultivar	No. of Pairs		No. of plants in which MXLR occurs in	
					Youngest visible leaf	Leaf immediately interior to YVL
1968	Fort Collins	White Portugal	48	0.950	41	7
	Field	54 - 306 B	48	0.952	44	4
		White Ebenezer	48	0.930	44	4
		White Sweet Spanish	48	0.963	42	6
		Ia 42 B	48	0.879	44	4
		2190 B	48	0.891	40	8
		B 12115-2	48	0.899	46	2
Percentage from total					90	10

practicality and accuracy may be reached by using the YVLRs if plants are field grown. Perhaps a greater degree of accuracy would be sacrificed in the greenhouse by not obtaining the MXLR, since more MXLRs were found in the leaf interior to the youngest visible leaf.

1.3.2. External minimum leaf ratio.

1.3.2.1. Change in means with plant age.

Mean external minimum leaf ratios at successive ages are shown in Figures 3A, 4A, 6A1, 6A2 and 7A for plants of several cultivars grown under varied environmental conditions. They show that the change in these means with plant age was either slight or did not follow a definite pattern. Also, no apparent relationship between such changes and scale formation (Figures 3B, 4B, 6B1, 6B2 and 7B), can be noticed. Thus, data presented do not support use of mean external minimum leaf ratios as indicators of internal scale formation. Accordingly, no attempt was made to determine the position of the external minimum leaf ratio on the plants.

1.3.2.2. External minimum leaf ratios of individual plants.

Table 13 in section 1.3.1.3. shows the correlation coefficients for ln IMNLRs and EMNLRs, for two cultivars, each grown under different conditions. Correlation coefficients were statistically non significant. Values of these correlations were -0.172 and -0.201 for the variety 'White Portugal' grown in the greenhouse at Fort Collins in 1967 and in the field at Fort Collins in 1968, respectively. In the inbred 'B 2190 B', correlation coefficients were 0.004 and 0.261 under the latter two sets of conditions, respectively. Accordingly, the external minimum leaf ratio of individual plants cannot be accurately utilized to predict internal scale formation.

1.4. Sheath lengths of the youngest visible leaves and of leaves with maximum leaf ratio.

1.4.1. Mean lengths.

Results presented in Figures 11A and 12A for the hybrid 'B 2190 A x Colorado 6', show that scale formation was accompanied by or was directly preceded by an increase in the mean sheath length of the youngest visible leaf, and of the leaf with maximum leaf ratio. The figures also show that this relationship was consistent, regardless of the environmental conditions under which the plants were grown. Data based on means of 20 plants of the same hybrid, grown under another set of conditions, are presented in Table 19. These data also show that much longer sheaths of the youngest visible leaves and of leaves with maximum leaf ratios occur in plants with scales than in plants without scales.

Means of sheath lengths of youngest visible leaves and of sheaths of leaves with maximum leaf ratios are presented in

Tables iv, vii, and viii for groups of cultivars grown under varied conditions. Except where noted, means in Figures 11A and 12A and in Tables iv, vii, and viii were based on six plants. These data show that scales were seldom found when the mean sheath length of leaves with MXLR's was less than 0.65 cm. The few exceptions occurred in the cultivar 'White Portugal' (Table ix), '1900 A x B 2190 B' (Table vii), 'White Portugal' and 'Ia 42 B' (Table iv).

In the majority of cases listed in Tables iv, vii, and viii and in those shown in Figures 11A and 12A, scales were found to occur when either one or both of the following criteria were present. Either the sheath length exceeded 0.65 cm, or the length was doubled since the previous weekly sample. Mean sheath length increased prior to scale formation in some cases in Figures 11A and 12A (rows designated A, B and C). The cultivars '1900 A x B 2190 B' (Table vii);'Ia 42 B' and 'White Portugal' (Table iv); 'B 1288 B', 'Ia 2997 B' and 'B 5546 B' (Table viii) are also exceptions. The exceptions occurred in early and late bulbing cultivars, in cultivars with bulbs of various shapes and sizes, and in plants grown under various environmental conditions. Because of these exceptions to this relationship between sheath lengths and scales, this means of identifying bulbing cannot be considered reliable.

The use of mean sheath lengths of the youngest visible leaves was disregarded, since occasionally young, non-bulbing plants have

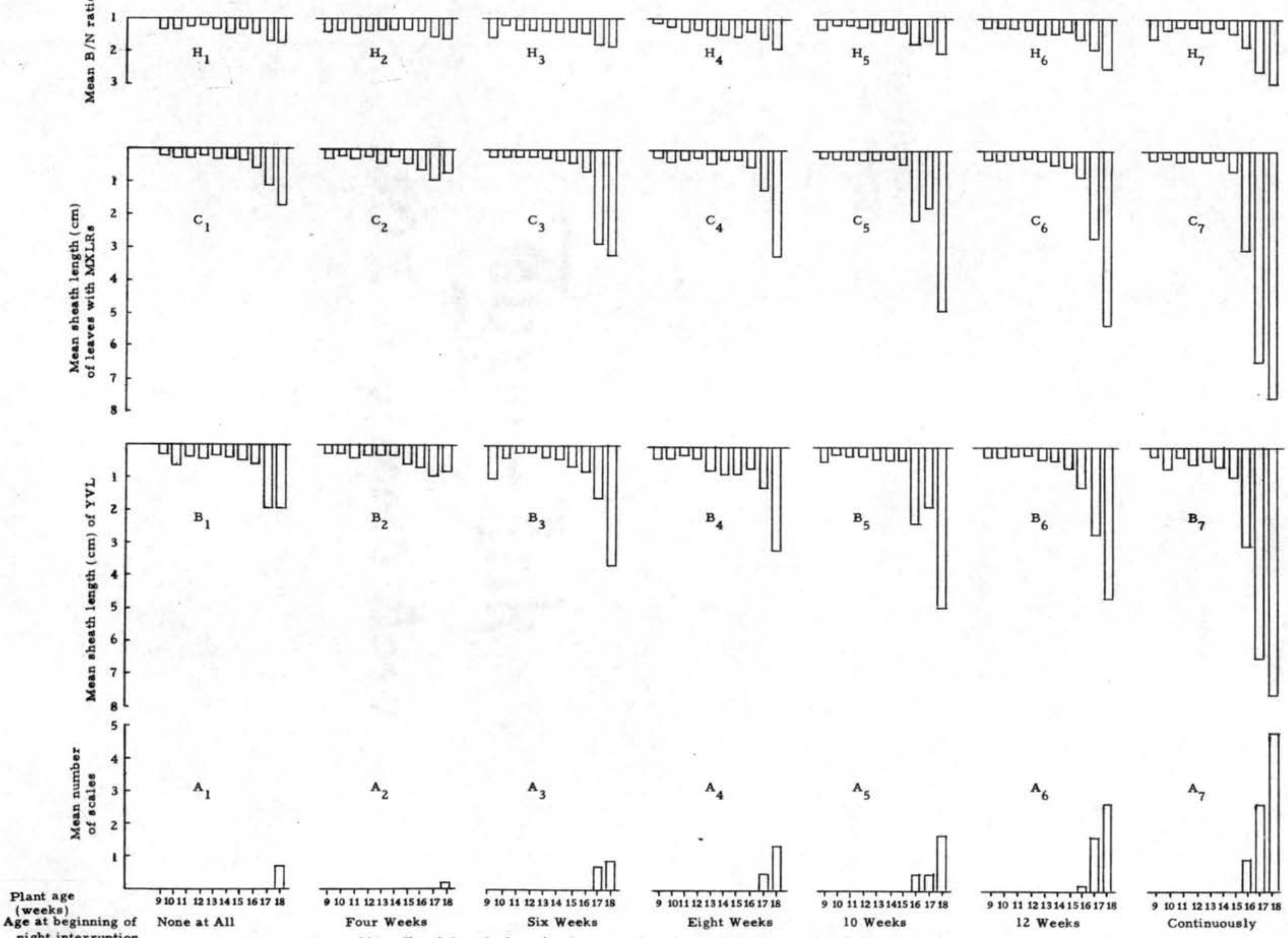


Figure 11A. **Sheath length, base/neck ratio and scale number compared as bulb initiation symptoms from night interruption study (Experiment 6). Data presented are mean values from six plants of hybrid 'B 2190 A x Colorado 6'.**

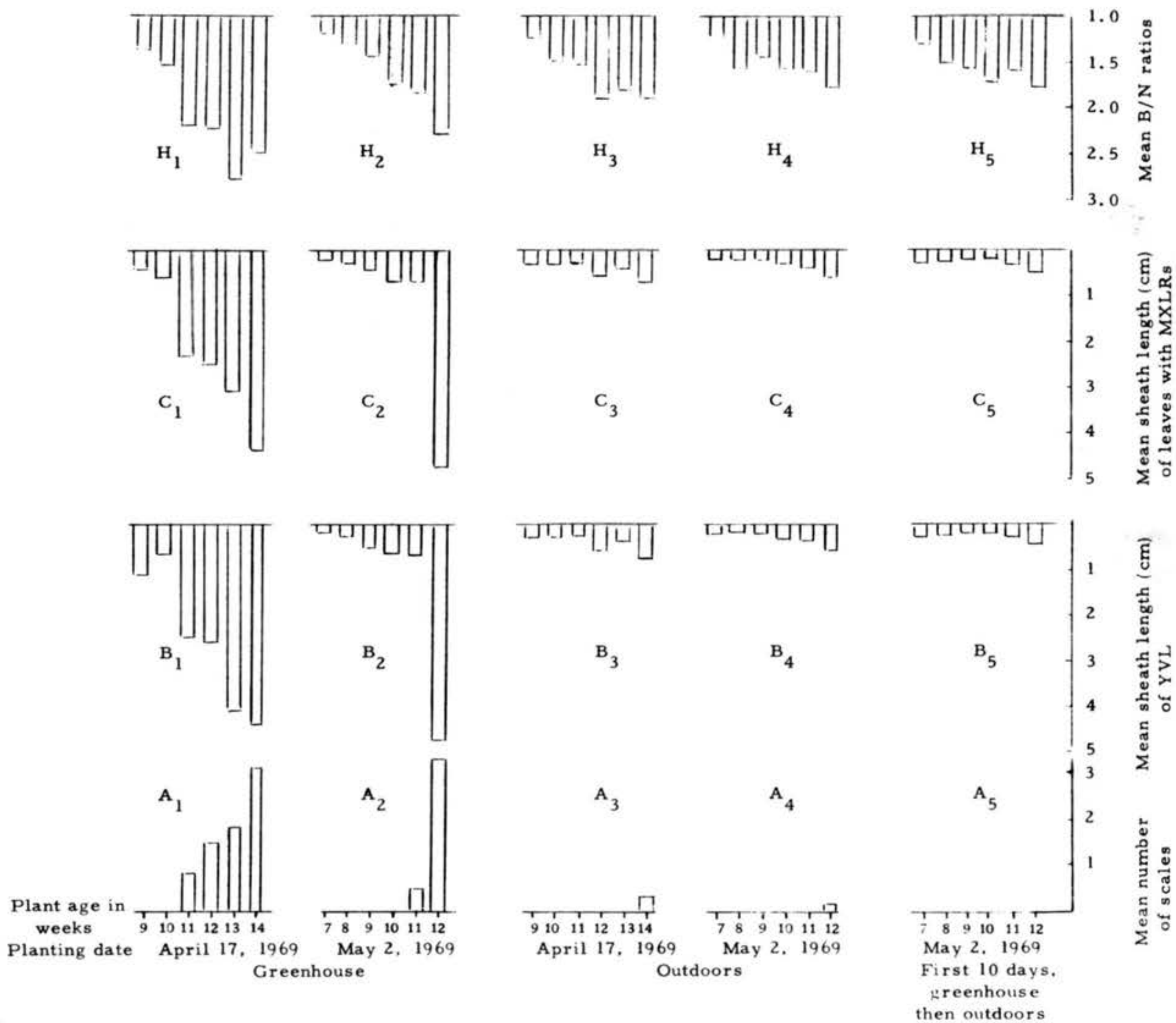


Figure 12A. Sheath length, base/neck ratio and scale number compared as bulb initiation symptoms from temperature study (Experiment 7). Data presented are mean values from six plants of hybrid 'B 2190 A x Colorado 6'.

sheath lengths longer than 1.00 cm. Examples of this observation are found in some cases in Tables iv, vii, and viii and in Figures 11A and 12A.

1.4.2. Sheath length of leaves with maximum leaf ratios (individual plants).

The distinct elongation of sheaths of leaves with maximum leaf ratios as scales were formed, is shown in Table 19 in section 2.5. and Figures 11A and 12A. This observation makes the consideration of equating scale formation with development of long sheaths inevitable. The discrepancy noticed with using mean values for sheath length could have been mainly due to the contribution of sheath lengths of plants without scales. Mean sheath length of leaves with maximum leaf ratios in plants with one, with more than one and without scales are shown in Tables i, ii, x, xi, xii, and xiii and in Figures 13 and 14. It can be seen that in no single case in which scales were formed, were the mean sheath lengths of leaves with maximum leaf ratios below 1.00 cm. On the other hand, in the majority of cases, plants without scales showed mean sheath lengths of leaves with maximum leaf ratios less than 1.00 cm. There were few cases in which the mean sheath length of leaves with maximum leaf ratios were greater than 1.00 cm and there were no scales. These cases were nearly all found in Table xiii. Three of these cases are shown in Table 16. A considerable number of these exceptions developed lateral buds instead of scales. Conceivably, as reported by Jones and Mann (1963), lateral buds contribute to the basal thickening of plants to form the bulb. A few other plants which neither formed scales nor developed lateral buds had unexplained sheath length of leaves with maximum leaf ratios longer than 1.00 cm. However, it may be that elongation of sheaths of the maximum ratio leaf precedes scale development. Another small group of plants developed lateral buds and yet had sheath lengths of leaves with maximum leaf ratios less than 1.00 cm. Selection of plants with sheath length of more than 1.00 cm from the sample tested would thus have been almost entirely for those plants in which scales had been formed. Selection of plants with smaller sheath lengths would have been mainly for those in which scales had not been formed. Since lateral bud development can also be detected at this time, it is possible that selection against 'internal doubling' (Shalaby, 1966), can also be automatically effected in this manner.

1.5. Plant height.

1.5.1. Mean plant height.

It is obvious that there is no absolute plant height value at which bulb initiation takes place. Some cultivars are known to mature with much shorter leaves than other cultivars have long before bulb initiation takes place.

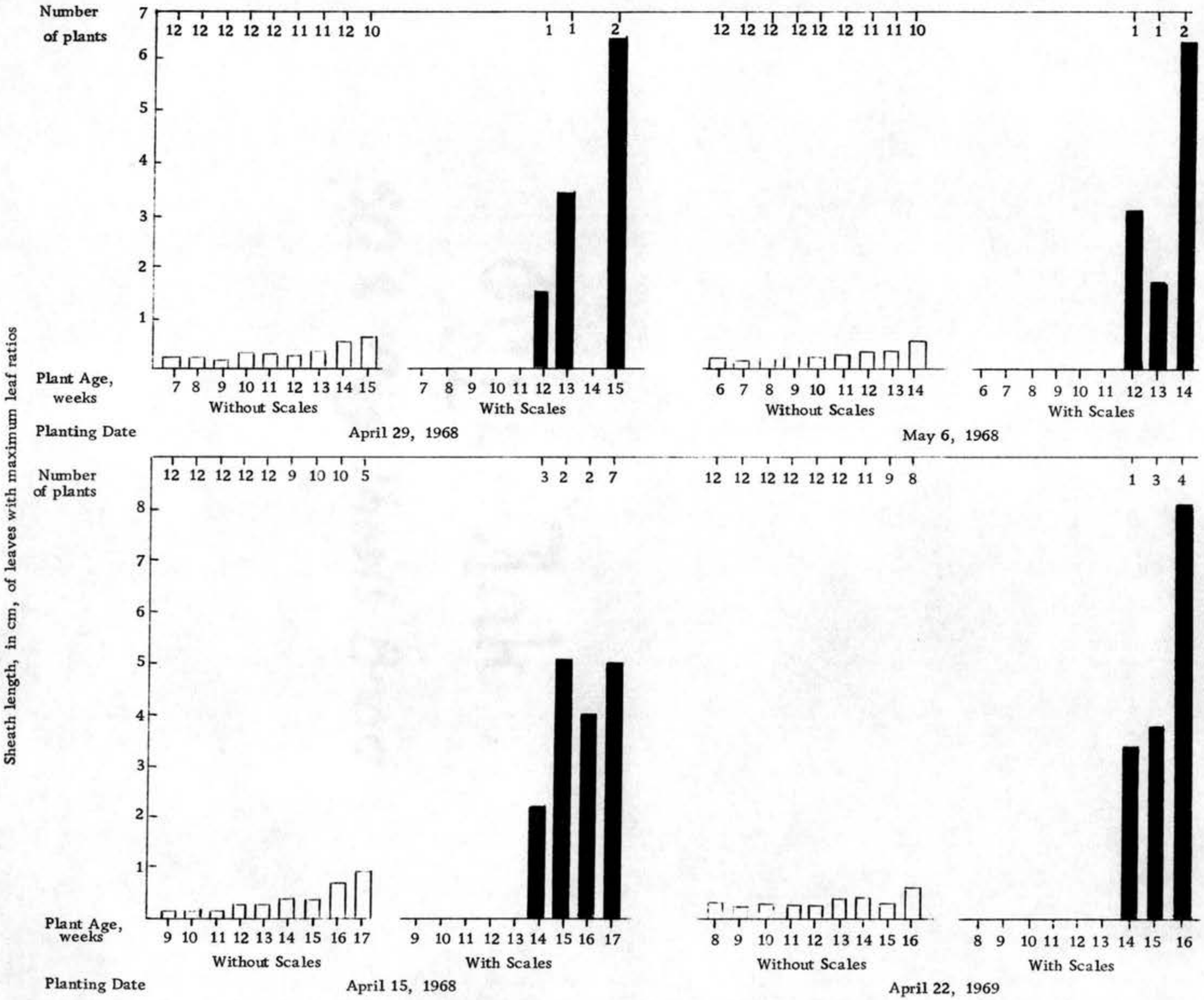


Figure 13. Mean sheath lengths of leaves with maximum leaf ratios from plants with and without scales. Data from date of planting study (Experiment 4), using the variety 'White Portugal'.

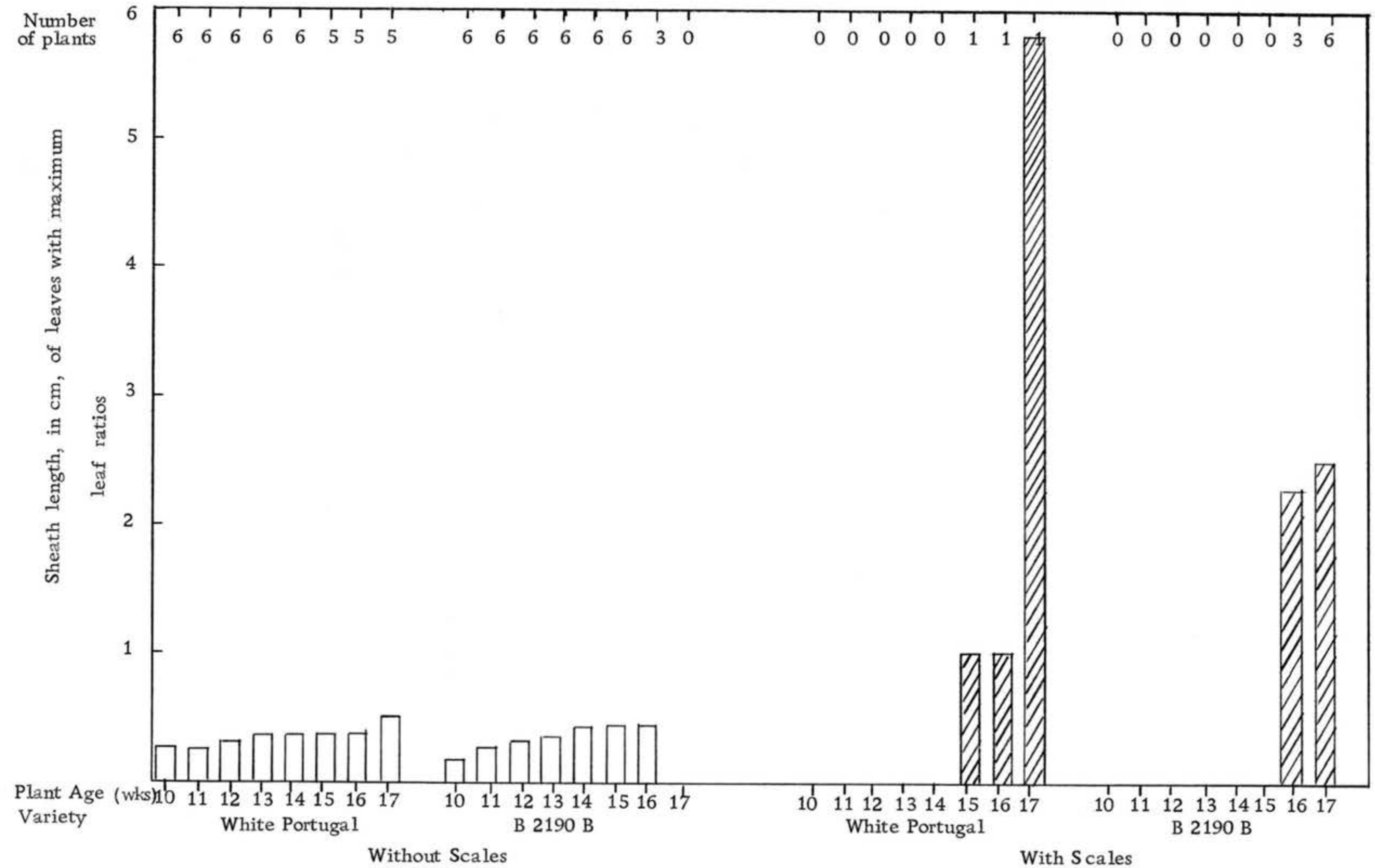


Figure 14. Mean sheath lengths of leaves with maximum leaf ratios from plants with and without scales. Data from two field grown cultivars, Fort Collins, 1968 (Experiment 3).

Table 16. Sheath length (cm) of leaves with MXLR of three cultivars, with and without scales and lateral buds. Plants were field grown at Fort Lupton, 1969 (Experiment 5).

Cultivar	Scales	Lateral buds	No. plants with sheath length range of			
			.1 - 1.0	1.1 - 2.0	2.1 - 3.0	> 3.0
White Ebenezer	Absent	Absent	7	0	0	0
		Present	3	2	0	0
	Present	Absent	0	0	2	0
		Present	0	3	1	12
B 2190 B	Absent	Absent	24	10	0	0
		Present	0	2	5	0
	Present	Absent	0	0	3	3
		Present	0	1	5	36
Ia 42 A x Colorado 6	Absent	Absent	26	5	1	0
		Present	5	7	3	1
	Present	Absent	0	0	1	2
		Present	0	1	3	34

Observations were made, however, to determine whether or not environmental factors influencing plant height of a given cultivar also influenced bulb initiation.

Table 19 presents the mean plant height for the hybrid 'B 2190 A x Colorado 6' grown under three photoperiodic treatments. Plants kept under naturally prevailing photoperiod (14 to 13 hours) were significantly taller than those grown under either nine hours of natural daylight or naturally prevailing daylength and continuously interrupted nights. Mean plant heights was 32.2 cm for plants of the first treatment, 25.6 cm for the second and 26.7 for the third. The latter two means were not statistically different. No scales were formed in plants of the first and the second treatment. All plants of the third treatment, with a mean height statistically similar to that of the second, formed scales. This indicates the lack of relationship between mean plant height and internal formation of scales.

1.6. Mean number of leaves.

Early work (Hector, 1936) indicated that onions bulbed when a given number of leaves were formed. Observations during this study indicated that this did not occur.

Table v shows the mean number of leaves of the hybrid 'B 2190 A x Colorado 6' exposed to night interruption at different ages. Mean number of visible leaves progressively increased with age under all treatments. The interaction between plant age and treatments was statistically non-significant. Scale formation occurred in plants with different number of leaves at different ages. Examination of Tables iv, vii, viii, ix for mean number of visible leaves show that the variety 'White Ebenezer' and the inbred 'B 2190 B' each showed different means at which scales were formed. The Tables include results for plants of the latter two cultivars, grown in the greenhouse at Fort Collins, in 1967 (Tables vii and ix), in the field at Fort Collins in 1968 (Table iv) and in the field at Fort Lupton in 1969 (Table viii). Under the latter three sets of conditions, means of number of visible leaves were 3.3, 8.2, and 10.2, respectively, for the inbred 'B 2190 B'. For plants of the variety 'White Ebenezer', the corresponding means were 3.7, 8.0, and 8.2. The means were so distinctly different to make the use of either the mean number of visible leaves or number of visible leaves of individual plants obviously inaccurate to predict scale formation.

1.7. Best criterion to predict internal scale formation.

Table 17 summarizes results on different reported criteria to diagnose internal scale formation. Several criteria are presented for different cultivars, under uniform and varied conditions, and a single cultivar under varied conditions. The closest correspondence to number of plants with scales appears to be number of plants with maximum leaf ratio of 10 or less. As previously shown, scale formation has been considered to be the earliest sign of bulb initiation.

Table 17. Comparison of various bulb initiation symptoms with scale formation (last column) in several experiments.

Experiment	Sampling date, treatment, or cultivar.	Number of plants with: Sheath length of leaves with MXLR ≥ 1 cm	Sheath length of YVL ≥ 1 cm	B/N ratio ≥ 2	YVLR <15	YVLR <10	MXLR <15	MXLR <10	Scales
7	Sample of 6-26-69	0	1	0	0	0	0	0	0
	" " 7-3-69	2	4	5	4	2	3	2	2
	" " 7-12-69	2	6	10	3	2	3	2	2
	" " 7-18-69	4	6	8	6	5	5	4	4
	" " 7-25-69	12	12	16	11	8	10	8	11
	Subtotal	20	29	29	24	17	21	16	19
6	Sample of 5-5-69	0	5	0	2	0	1	0	0
	" " 5-12-69	6	11	6	9	5	7	4	5
	" " 5-19-69	21	23	12	22	16	21	15	12
	" " 5-26-69	27	31	19	23	21	21	20	20
	Subtotal	54	70	37	56	42	50	39	37
8	First treatment	0	1	0	0	0	0	0	0
	Second treatment	0	1	0	1	0	1	0	0

Table 17. (cont.)

Experiment	Sampling date, treatment, or cultivar.	Number of plants with: Sheath length of leaves with MXLR ≥ 1 cm	Sheath length of YVL ≥ 1 cm	B/N ratio ≥ 2	YVLR <15	YVLR <10	MXLR <15	MXLR <10	Scales
8	Third treatment	20	20	20	20	20	20	20	20
	Subtotal	20	22	20	21	20	21	20	20
1	8875 B	12	15	7	15	13	12	11	9
	1288 A	16	17	6	21	17	21	16	16
	1288 A x 8875 B	13	13	12	14	12	14	12	13
	Colorado 761	0	9	1	11	9	4	1	0
	2997 A	8	9	7	12	11	11	10	10
	2997 A x Colorado 761	7	13	4	13	11	9	6	7
	B 2190 B	12	15	5	13	13	12	11	12
	1900 A	10	17	6	17	15	14	9	9
	1900 A x B 2190 B	11	17	7	15	15	11	11	13
	1900 A x Colorado 6	6	9	3	10	9	7	5	7
	Colorado 6	7	13	7	14	11	10	7	6
	Subtotal	102	147	65	155	136	125	99	102
	Total	196	262	181	253	215	216	174	178

2. Factors affecting bulb initiation.

MXLR was reported in the previous section to adequately indicate bulb initiation. Since the determination of the MXLR is far more rapid than the determination of IMNLR, the former will be used in succeeding sections when reporting bulbing, unless otherwise specified. Plants with a MXLR of 10 or less will be considered to have initiated bulbs.

2.1. Genotype

No investigations of heritability or of genetic structure of bulb initiation were undertaken. Some observations of data assembled for other purposes, however, might be described in terms of inheritance.

Experiments 1, 2, 3, and 4 were all conducted with several cultivars each. An examination of Tables iv, vii, viii, and ix verifies the obvious assumption that a group of cultivars grown in the same environment, whether they are inbreds, hybrids or open pollinated varieties, differed in the age at which bulbing began. This fact, of course, is commonly known and references to cultivar differences have been made throughout this study; therefore, supporting data are not presented here.

Four F_1 hybrids and their parents were examined in the hope that at least some information on the dominance of genes affecting bulbing could be obtained (Table vii). The inbred 'Colorado 761' showed no bulbing at the time sampling was terminated. The plants were six weeks old. Another inbred, 'Ia 2997 A', began bulbing at the age of five weeks. The F_1 hybrid with these inbreds as parents began bulbing at the age of four weeks, and this could be considered either a manifestation of heterosis or some other form of gene interaction.

All hybrid comparisons, however, did not fit this pattern. Two of the hybrids began bulbing at the same time as the later parent and the fourth was one week later than both parents. A case was thus not made for manifestation of heterosis in time of bulb initiation.

The following two examples demonstrate another obvious conclusion that has been commonly understood: a given genotype can be induced to initiate bulbing at different ages when grown in different environments. The variety 'White Ebenezer' and inbred 'B 2190 B' were greenhouse grown at Fort Collins in 1967 (Tables vii and ix), and field grown at Fort Collins in 1968 (Table iv) and at Fort Lupton in 1969 (Table viii). Bulbing had begun, in the variety 'White Ebenezer' when plants were three, 15 and 13 weeks old, under the three sets of conditions, respectively. Corresponding figures for the inbred 'B 2190 B' were four, 15 and 14 weeks.

2.2. Temperature

The effect of temperature on bulbing was investigated in experiment 7. Greenhouse vs. outside-grown plants of the hybrid 'B 2190 A x Colorado 6' were compared. Plants received the same cultural practices inside and outside the greenhouse. Natural photoperiod was the same. Light intensity and quality were essentially the same, according to Goldsberry (1967). Only the temperature regime was different. Minimum temperature was set at 60° F inside the greenhouse. Outdoors, mean minimum temperatures, throughout the duration of the experiment, were 37.6, 45.3, 49.0 and 58.8° F for April, May, June and July. Trials were planted on April 19 and May 2, 1969.

Results presented in Table vi, indicate that greenhouse grown plants from both planting dates first showed scale formation when 11 weeks old. Scales were not formed in those grown outdoors until later, and they were first observed in samples from the two planting dates on the same date, July 25. Plants from the first planting date were thus two weeks older than those planted second when bulbing was first observed.

Two aspects of temperature effect on bulb initiation were demonstrated by this experiment. First, bulbing occurred earlier in the greenhouse grown plants. In the second place, the response to planting dates was different between greenhouse and outdoors plants. In the greenhouse, where minimum temperatures were higher, the plants from both planting dates responded at the same age, but at different dates to increasing daylength.

If we use the criterion of numbers of plants with MXLR of 10 or less to distinguish those in which bulbing was initiated, the plants grown outdoors did not bulb. However, two successive reductions in MXLR occurred and scales were found on July 25, in plants from both planting dates. Thus, the earlier planting first showed bulbing when the plants were 14 weeks old and the second planting when the plants were 12 weeks old. The lower temperatures outdoors apparently delayed the response to daylength.

2.3. Planting dates.

Seeds of the variety 'White Portugal' were sown at weekly intervals, from April 15 to May 6, 1968, in the field at Fort Collins. Mean number of bulbing plants at successive ages and sampling dates are shown in Table xiv. Seeds sown on April 15 resulted in plants that bulbed on July 23, when plants were about 14 weeks old. Later plantings resulted in plants that bulbed at the same date, i.e., July 30, but at different ages. Ages at which those plants bulbed were 14, 13 and 12 weeks, for the latter three planting dates, respectively. Plants tended to bulb at younger ages, as planting date was delayed from April 15 and 22 to May 6, 1968. Evidently, earlier plantings caused a delayed response to increasing daylength because of lower temperatures early in the growing season.

This trend in temperature effect on bulbing is supported by the results obtained from experiment 7, discussed in the preceding section.

The earlier the planting date, the more bulbing plants produced by the end of sampling, with the exception of the third planting date. Mean numbers of bulbing plants were .32, .22, .08 and .14, for the four planting dates, respectively. The present investigation does not provide a satisfactory explanation for such behavior. It is possible, however, to assume that onion plants become more sensitive to the increasing photoperiod, as they grow older and/or larger. Also it is possible to assume that the photoperiodic stimulus is more effective at higher temperatures.

2.4. Night interruption and plant age.

Experiment 6 was designed to study the effect of night interruption at different plant ages on the bulbing process. The night interruption was effected by exposing plants to one hour of incandescent light at midnight, for a two week period. Mean numbers of bulbing plants are presented in Table 18, with a detailed report in Table v.

Numbers of bulbing plants were counted when the plants were 18 weeks old. At that time bulb initiation had occurred in all treatments except the one in which light exposure was given at the age of four weeks. By every criterion of bulbing, there was more bulbing and earlier initiation among the plants receiving night interruption for all 18 weeks than among control plants.

There is also an indication that light interruption was more effective when applied to older plants. When it occurred at four weeks, there appeared to be even a suppression of bulbing. The first significant treatment was induction at 12 weeks. Continuous induction produced significantly more bulbed plants than the 12 week treatment. Thus it appears that both age at time of light induction and length of treatment modify the effects of night interruption. The effects of plant age tend to support the suggestion made from the results in sections 2.2. and 2.3. that onion plants become more responsive to factors favoring bulb initiation as they become older and/or larger.

2.5. Length of photoperiod and night interruption.

Experiment 8 was designed to further establish the effect of night interruption. This experiment was also designed to study the effect of length of photoperiod on the bulbing process. Plants of the hybrid 'B 2190 A x Colorado 6' were exposed to three treatments. First was the exposure of plants (at the age of two weeks) to nine hours photoperiod. Plants to receive the second treatment were left under natural photoperiod that prevailed from June 18 (about 14 hours) to August 5 (about 13 hours). In the third treatment, plants were also left under natural photoperiod that prevailed from June 18 to August 5, and in addition, continuously received an hour of incandescent light at midnight. Light interruption began when the plants were two weeks old and continued daily until the end of the experiment, when plants were seven weeks old.

The number of bulbing plants, on August 5, are shown in Table 19, along with other morphological features. The effect of night interruption is obvious. All (20) sampled plants from the night interruption treatment bulbed. Treatments which did not receive night interruption did not produce any bulbing plants.

Several morphological effects were noted. The first and the third treatments resulted in the production of shorter plants than those produced by the second treatment. Mean heights were 25.6, 26.7 and 32.2 cm for the first, third and second treatments, respectively, with no significant difference between the first and the second means. The highest number of visible leaves were found in plants that received the second treatment, followed by those which received the first treatment. The third treatment resulted in plants with the least number of visible leaves. Mean numbers of visible leaves were 5.4, 4.3, and 3.6, for the second, first and third treatments, respectively. It is obvious that vegetation was decreased in plants that received the first and the third treatments as compared to those which received the second treatment. It appears that shorter photoperiods in the first treatment and the shift toward bulb formation in the third treatment are responsible for the decrease in vegetation.

Bulb formation, as evidenced by either base/neck ratios much greater than 1.00 or formation of scales, occurred only in plants which received the night interruption treatment. Mean base/neck ratios were 1.20, 1.19 and 3.04 for plants which received the first, the second and the third treatments, respectively, while mean number of scales per plant were 0, 0 and 3.1.

A photograph showing the distinct morphological differences between plants that received each of the three treatments is presented in Figure 15.

Mean YVLRs were 42.1, 29.6 and 3.1 for plants exposed to the first, second and third treatments, respectively, with a significant difference among means. Corresponding mean MXLRs were 43.1, 30.4 and 3.1, which are statistically different.

Mean sheath length of the youngest visible leaves proved to be the highest in plants exposed to the night interruption treatment. Means were 4.44, .28 and .41 cm for plants which received the third, the first and the second treatments, respectively, with no significant difference between the latter two means. The same trend is noticed with means of sheath lengths of leaves with maximum leaf ratios.

Experiments 6 and 8 have thus demonstrated the effectiveness of one hour night interruption in inducing bulb initiation. Bulb initiation had progressed further in experiment 8 with seven week old plants than in experiment 6 with 18 week old plants, even though treatments were similar. Since natural daylength was shorter during the sixth experiment, which was begun in January, these results support the suggestion of Kato and Oyer (1969) that night interruption is more effective when daylength is near that required for bulb initiation.

3. Prediction of maturity.

Since it was found that certain morphological changes, particularly in sheath elongation and leaf ratios, were symptomatic of bulb initiation, the possible use of these changes in predicting comparative time to maturity among cultivars was considered. The following study was based on the untested assumption that differences among cultivars in time from planting to bulb initiation are correlated with time from bulb initiation to maturity of the bulb.

First consideration was given to a bulb initiation symptom that could be obtained quickly and with little experience. This approach to maturity prediction was explored for its possible use in early selection of cultivars for earliness.

Percentage of plants with tops down on August 28, 1969, was used as a measure of maturity. This percentage was correlated with plot means of characters measured for plants at the age of 14 weeks of the 23 cultivars grown in the field at Rocky Ford, in 1969. The field trial from which these samples were taken was a yield trial with six replications. Data from such trials are usually presented on the basis of the mean of each cultivar for all replications. Correlations were thus also computed on the basis of these cultivar means.

With correlation coefficients based on plot means (Table 20), the highest correlation with percent tops down was obtained by using the youngest visible leaf ratio (YVLR). The next highest was obtained by using the number of plants with sheath length of youngest visible leaves greater than one cm. These two correlations were -.633 and .601; both were highly significant.

Of the two techniques, it is easier to obtain the number of plants per plot, in which a given sheath length is exceeded than it is to measure all sheaths and blades to obtain an average value of leaf ratios. Therefore, the number of plants having sheaths longer than one cm, were used in computing correlation coefficients with percent tops down on the basis of cultivar means, rather than plot means. The resulting correlation was .796, compared with .601. The ρ values using cultivar means indicated that there is a 95 percent probability that the population correlation coefficient will lie between .60 and .91. Plotting of the two variables along with the regression line, is shown in Figure 16. From the regression equation, it can be noted that the regression coefficient was .59. This means that for each increase of 10 percent of plants with sheath lengths of the youngest visible leaves of one cm or greater, percent tops down would be increased by 5.9.

Differences among cultivars in length of time from bulb initiation to maturity, as well as environmental effects on this period of plant development were not studied. Such studies could lead to a utilization of this technique in predicting harvest dates.

Table 18. Bulb initiation following night interruption for two weeks by incandescent light for one hour nightly at midnight. Samples of six plants from each treatment were examined weekly for 11 weeks.

Plant age when treatment began	Mean no. bulbing plants (MXLR $\leq$10)	Age (weeks) when bulbing began	Mean no. scales	B/N ratio
Control	1.00	17	0.67	1.75
Four weeks	0.00	18+	0.00	1.63
Six weeks	2.50	17	0.83	1.85
Eight weeks	2.00	17	2.17	1.89
Ten weeks	2.50	16	1.67	2.04
Twelve weeks	4.00	17	2.67	2.54
Continuous	7.50	16	4.83	2.98
L. S. D. (.05)	1.68			

Table 19. Effects of night interruption on bulb initiation in the hybrid 'B 2190 A x Colorado 6' (Experiment 8). Treatments 1 and 3 began at the age of two weeks and data were obtained at the age of seven weeks. Means are based on 20 plants.

Treatment	B/N ratios	Youngest visible leaf: Sheath length (cm)	Youngest visible leaf: YVLR	No. scales	No. visible leaves	Plant height (cm)	Leaves with maximum leaf ratio: Sheath length (cm)	Leaves with maximum leaf ratio: MXLR	Bulbing plants (with MXLR ≤10)
1. Sunlight, nine hours.	1.20	.28	42.1	0	4.3	25.6	.23	43.1	0
2. Sunlight, normal daylength.	1.19	.41	29.6	0	5.4	32.2	.32	30.4	0
3. Sunlight, normal daylength, and one hour of nightly incandescent light at midnight.	3.04	4.44	3.1	3.1	3.6	26.7	4.44	3.1	20
L. S. D. (.05)	1.03	.49	3.7	.24	.3	1.6	.49	2.8	--

Figure 15. Bulb development under three photoperiod regimes: (1) 9 hours of natural light, (2) naturally decreasing photoperiod of 14 to 13 hours, and (3) naturally decreasing photoperiod plus night interruption with incandescent light for one hour at midnight. Photograph taken at the age of seven weeks.


1
2
3

Table 20. Correlation and regression coefficients between percent tops down, and several bulb initiation symptoms recorded at the age of 14 weeks from variety trial at Rocky Ford (Experiment 9). Calculations were based on individual plot values.

Characters, recorded at the age of 14 weeks, correlated with percent tops down on August 28, 1969	Regression coefficient (b)	Correlation coefficient	
		r	95 percent confidence limits for ρ
Mean base/neck ratio.		.359**	.20 - .52
Mean sheath length of youngest visible leaves.	12.9	.531**	.37 - .64
Mean youngest visible leaf ratio.	-2.4	-.633**	(-.53)-(-.73)
Mean number of scales.		.425**	.257 - .553
Mean number of visible leaves.		-.067[1]	
Number of plants with sheath lengths of youngest visible leaves ≥ 1 cm.	7.2	.601**	.455 - .700
Mean number of growing lateral buds.		.225*	(-.15) - .58

* Significant at .05 level

** Significant at .01 level

1 Statistically non-significant

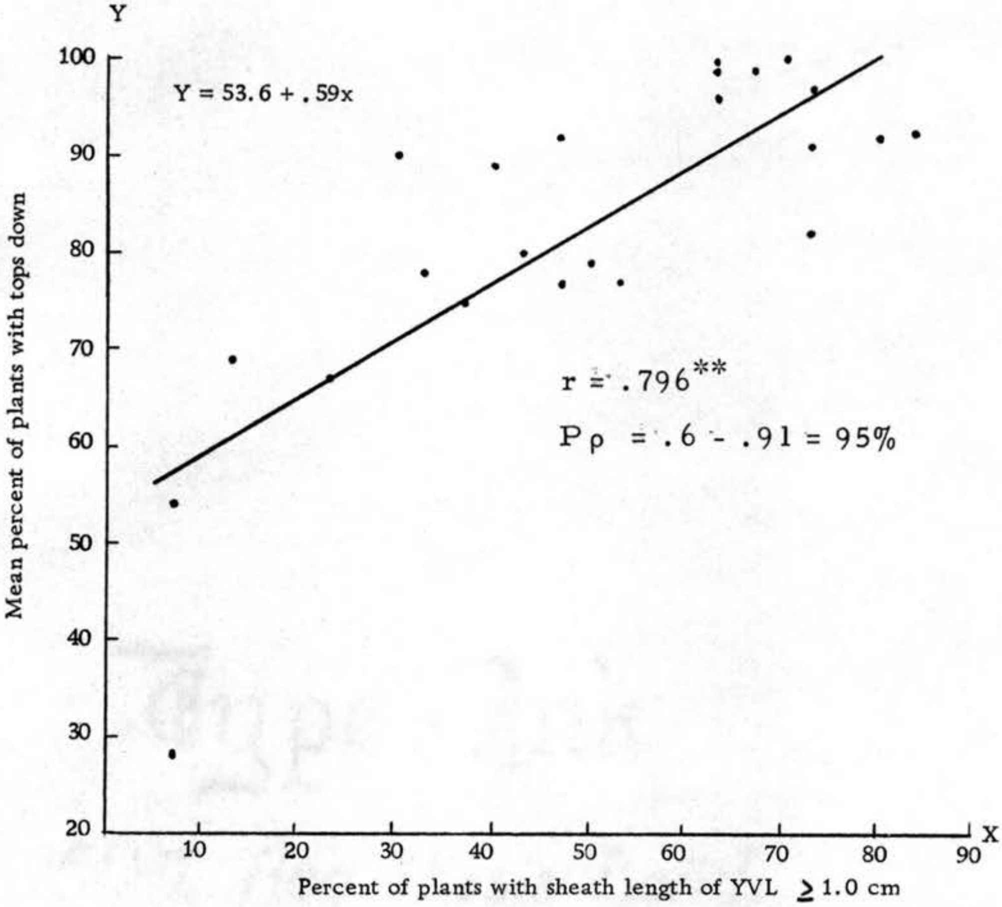


Figure 16. Percent of plants with youngest visible leaf sheath lengths ≥ 1.00 cm at the age of 14 weeks plotted against percent of plants with tops down, on August 28. Data from variety trial, Rocky Ford, 1969 (Experiment 9) and values are means of six replications.

CONCLUSIONS

Bulb initiation symptoms were evaluated on the basis of accuracy, reliability and simplicity. For further research on bulbing, investigations of the first morphological changes in the bulbing process were made. Other methods were investigated for possible use in field modifications of bulb initiation and development and in early prediction of bulb maturity.

The base/neck ratio was found to be unreliable in diagnosing bulb initiation. Ratios of leaf blade and sheath lengths were studied. Reduction in the maximum leaf ratio (MXLR) and in the youngest leaf visible without dissection (YVLR) preceded internal scale formation, which is a known part of the bulbing process.

MXLR of 10 or less, on a given plant, signalled internal scale formation. This MXLR usually occurred on the youngest visible leaf. This was more frequently observed in field grown than in greenhouse grown plants. Accordingly, a YVLR of 10 or less can be used to diagnose internal scale formation in field grown plants. Where the MXLR did not occur in the youngest visible leaf, it was always found to occur in the first leaf interior to it.

Sheaths of youngest visible leaves or leaves with MXLR elongated prior to or concomitant with internal scale formation.

The sheath length at or beyond which scale formation can be predicted was not established.

Several methods for detecting bulb initiation were found to be less satisfactory. The construction of graphs of all leaves on a plant (Heath and Hollies, 1965) is a lengthy procedure; furthermore, this method detected scale formation later than other methods studied.

Mean ratios of youngest visible leaves, which were found to steadily decrease prior to or along with scale formation, were also not as reliable in prediction of scale formation as individual plant ratios. Neither a definite time from the first decrease to scale formation nor an absolute value of mean YVLR at which scales were formed could be established.

As noted above, the leaf ratios of youngest visible leaves decrease prior to scale formation. Removal of youngest visible leaves was not carried out in this study. However, the reduction in their leaf ratios, along with results of experiments involving their removal by Kato (1965), suggest their important role in perception of external stimuli for bulbing and/or translocation of substances formed in response. Removal of blades of youngest visible leaves may be tried as a breeder's tool in retarding bulb initiation. This could affect the final bulb size through control of the number and vigor of foliage leaves at the time of bulb initiation.

Plant vigor, in terms of height and number of visible leaves, was found unreliable to predict internal scale formation. However, the number of visible leaves at the time of scale formation may not be disregarded, since studies have shown that it determines the final bulb size (Imazu et al., 1954 and Jones and Mann, 1963).

Varietal behavior in bulb initiation confirmed two commonly known phenomena. First, under fairly uniform conditions, cultivars differed in the age of bulb initiation. Secondly, plants of a given cultivar differed in that age when grown under different conditions. The behavior of hybrids and corresponding parents showed no manifestation of heterosis of genes controlling the bulb initiation in onion.

Effect of temperature on bulb initiation was obtained by comparing greenhouse and outdoor grown plants. Results indicated that the photoperiodic stimulus was more effective at higher temperatures. Inbreds and hybrids may be screened, accordingly, to possibly select temperature neutral cultivars. Those cultivars could be of economical value, as variability in yields, due to yearly fluctuations in temperature may be reduced to a minimum. Also, international breeding programs will benefit from growing such temperature neutral cultivars at different elevations on the same latitude.

Date of planting studies with field grown plants, indicated that bulbing occurred at younger ages as the date of planting was delayed. Under field conditions, the final bulb size, may be accordingly manipulated. However, under fairly uniform temperature conditions, as those which prevailed in the greenhouse at Fort Collins in 1969, such manipulation would not be possible. Plants tended to bulb at the same age regardless of the planting date.

Results of two experiments (6 and 8) using the hybrid 'B 2190 A x Colorado 6' established the effectiveness of incandescent light interruption at midnight in induction of bulbing. Results obtained from experiment 6, showed that a one hour light interruption at midnight for two weeks when plants were 12 weeks old was almost as effective in bulb induction as a one hour interruption for the whole plant life. There was also an increased responsiveness to this treatment with increased plant age or size. Kato and Oyer (1969) also induced bulb initiation by night interruption. They concluded that the effectiveness of this treatment depended on exposure of plants to a total daily illumination period near the critical daylength for the cultivar. In my studies the natural daylengths were from 13 to 14 hours, and it may be assumed that the critical daylength for this hybrid is near 14 hours.

In experiment 8, definite morphological effects resulted from lengths of photoperiods and incandescent light interruption at midnight. Short photoperiods (nine hours) and night interruption treatments resulted in reduced plant height and number of visible leaves, as compared to those resulting from the naturally decreasing (14 to 13 hours) photoperiod treatment. Also the reduction in YVLRs and MXLRs and the increase in sheath lengths of corresponding leaves toward scale formation, reported earlier, is confirmed by results of this study.

Measurements of 23 cultivars grown at Rocky Ford in 1969 were recorded when the plants were 14 weeks old. The maturity of the onion plants could be predicted from the percentage of plants with sheath lengths of youngest visible leaves of one cm or more. However, under growing conditions appreciably different from those of Rocky Ford, it is necessary to determine the exact age at which sheath length can be found to be closely related to maturity of cultivars.

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APPENDIX

Table i. Means for bulb initiation symptoms in plants of the hybrid 'B 2190 A x Colorado 6' with and without scales (Experiment 7). Data from all treatments were pooled.

Scales	Sampling date	B/N ratio	Youngest visible leaves: Sheath length (cm)	Youngest visible leaves: YVLR	Leaves with MXLR: Sheath length (cm)	Leaves with MXLR: MXLR	Plant height (cm)	No. visible leaves	No. plants
Without scales	5 - 29	1.24	.33	26.8	.21	28.3	15.0	1.9	30
	6 - 19	1.27	.42	32.0	.26	33.1	27.9	4.2	30
	6 - 26	1.48	.34	35.0	.29	36.1	33.1	5.4	30
	7 - 3	1.58	.47	35.7	.33	36.2	37.0	5.7	28
	7 - 12	1.77	.54	25.5	.41	29.1	41.6	6.4	28
	7 - 18	1.72	.52	29.6	.40	30.3	43.2	7.6	25
	7 - 25	1.79	.55	23.5	.52	23.7	46.7	8.6	19
With scales	6 - 26	---	---	---	---	---	---	---	0
	7 - 3	2.51	4.55	7.2	4.55	7.2	47.0	7.0	2
	7 - 12	2.60	5.60	4.4	5.60	4.4	53.2	8.0	2
	7 - 18	2.96	4.44	6.0	3.80	6.8	50.5	8.0	5
	7 - 25	2.51	4.94	7.1	4.94	7.1	50.0	8.4	11

Table ii. Means for bulb initiation symptoms in plants of the hybrid 'B 2190 A x Colorado 6' with no scales, one scale and more than one scale (Experiment 6). Data from all treatments were pooled.

			Youngest visible leaf		Leaves with MXLR				
Number of scales	Plant age (weeks)	B/N ratio	Sheath length (cm)	YVLR	Sheath length (cm)	MXLR	Plant height (cm)	No. visible leaves	No. plants
No scales	8	1.30	.70	25.4	.21	29.2	19.3	2.3	42
	9	1.39	.45	29.2	.24	29.9	22.4	3.0	42
	10	1.27	.36	36.4	.23	37.6	27.2	3.9	42
	11	1.32	.29	38.1	.27	38.7	29.7	4.9	42
	12	1.32	.31	45.7	.23	47.1	38.1	6.1	42
	13	1.40	.39	40.9	.31	41.9	41.5	7.3	42
	14	1.40	.46	41.3	.27	43.4	47.5	8.6	42
	15	1.41	.61	35.9	.39	37.5	51.8	9.7	42
	16	1.46	.75	31.4	.52	31.7	52.1	10.5	37
	17	1.61	1.17	23.5	1.03	23.8	61.5	11.9	30
	18	1.71	1.35	23.2	1.12	23.7	61.0	12.6	22
One scale	16	2.08	3.70	10.0	3.70	10.0	54.0	10.0	2
	17	1.90	2.75	6.4	2.75	6.4	63.9	12.5	2
	18	2.20	2.50	6.4	2.50	6.4	68.5	13.0	1
More than one scale	16	2.41	6.20	3.8	6.20	3.8	51.2	9.7	3
	17	2.44	5.40	4.5	5.40	4.5	55.9	11.2	10
	18	2.48	6.66	5.3	6.66	5.3	60.7	11.9	19

Table iii. Base/neck ratios and scale formation compared as bulb initiation signals in several cultivars.

Experiment	Cultivar	Age of plants (weeks)	Number of plants: B/N > 2 (no scales)	Scales and (B/N < 2)	Scales and (B/N > 2)	No scales and (B/N < 2)	Total
2	Early White Mexican	3	0	1	1	4	6
		4	0	2	3	1	6
		5	0	0	6	0	6
	Australian Brown	3	0	0	0	6	6
		4	0	2	3	1	6
		5	1	1	3	1	6
	Red Creole	3	0	3	0	2	5
		4	0	0	6	0	6
		5	0	0	6	0	6
	Yellow Ebenezer	3	1	0	0	3	4
		4	0	2	2	2	6
		5	0	0	3	2	5
	Southport White Globe	3	0	0	0	6	6
		4	0	4	0	2	6
		5	0	3	3	0	6
	White Portugal	3	1	1	0	4	6
		4	0	2	1	3	6
		5	1	3	1	1	6

Table iii (cont.)

Experiment	Cultivar	Age of plants (weeks)	Number of plants: B/N > 2 (no scales)	Scales and (B/N < 2)	Scales and (B/N > 2)	No scales and (B/N < 2)	Total
2	White Lisbon	3	0	0	0	6	6
		4	0	0	0	6	6
		5	1	0	3	2	6
	White Ebenezer	3	0	0	0	6	6
		4	0	3	1	2	6
		5	0	0	6	0	6
	Crystal White Wax	3	0	0	0	6	6
		4	0	2	3	1	6
		5	0	0	6	0	6
	Excel Bermuda	4	0	1	0	5	6
		5	0	1	4	1	6
		6	0	0	6	0	6
1	8875 B	3	0	0	0	6	6
		4	0	1	0	5	6
		5	0	0	3	3	6
		6	0	2	3	1	6
	1288 A	3	0	0	0	6	6
		4	0	3	0	3	6
		5	0	5	1	0	6
		6	0	0	6	0	6

Table iii (cont.)

Experiment	Cultivar	Age of plants (weeks)	Number of plants: B/N > 2 (no scales)	Scales and (B/N < 2)	Scales and (B/N > 2)	No scales and (B/N < 2)	Total
1	1288 A x 8875 B	3	0	0	0	6	6
		4	0	0	3	3	6
		5	0	2	3	1	6
		6	0	0	3	3	6
	Colorado 761	3	0	0	0	6	6
		4	0	0	0	6	6
		5	0	0	0	6	6
		6	1	0	3	2	6
	2997 A	3	0	0	0	6	6
		4	0	1	0	5	6
		5	0	3	1	2	6
		6	0	0	6	0	6
	2997 A x Colorado 761	3	0	0	0	6	6
		4	0	0	0	6	6
		5	0	3	1	2	6
		6	0	3	3	0	6
	B 2190 B	3	0	0	0	6	6
		4	0	2	0	4	6
		5	0	2	2	2	6
		6	0	3	3	0	6

Table iii (cont.)

			Number of plants				
Experiment	Cultivar	Age of plants (weeks)	B/N > 2 (no scales)	Scales and (B/N < 2)	Scales and (B/N > 2)	No scales and (B/N < 2)	Total
1	1900 A	3	0	0	0	6	6
		4	0	2	0	4	6
		5	0	4	0	2	6
		6	0	0	6	0	6
	1900 A x B 2190 B	3	0	0	0	6	6
		4	0	2	0	4	6
		5	0	4	1	1	6
		6	0	0	6	0	6
	1900 A x Colorado 6	3	0	0	0	6	6
		4	0	0	0	6	6
		5	0	2	0	4	6
		6	0	3	3	0	6
	Colorado 6	3	0	0	0	6	6
		4	0	0	2	0	2
		5	1	0	1	4	6
		6	0	1	3	2	6
3	54 - 306 B	14	0	0	0	6	6
		15	0	0	0	6	6
		16	0	0	1	5	6

Table iii (cont.)

Experiment	Cultivar	Age of plants (weeks)	Number of plants: B/N > 2 (no scales)	Scales and (B/N < 2)	Scales and (B/N > 2)	No scales and (B/N < 2)	Total
3	White Ebenezer	14	0	0	0	6	6
		15	0	1	1	4	6
		16	0	0	2	4	6
	White Sweet Spanish	14	0	0	0	6	6
		15	0	0	0	6	6
		16	2	0	1	3	6
	Ia 42 B	14	0	0	1	5	6
		15	0	1	1	4	6
		16	0	0	3	3	6
	12115-2	14	0	0	0	6	6
		15	0	0	1	5	6
		16	0	0	2	4	6
5	P 54 - 306 B	14	0	0	0	5	5
		15	1	0	0	4	5
		16	1	2	0	2	5
	White Ebenezer	12	0	0	0	5	5
		13	0	0	1	4	5
		14	1	2	0	2	5
	White Sweet Spanish	15	0	0	0	5	5
		16	1	2	0	2	5
		18	0	2	3	0	5

Table iii (cont.)

Experiment	Cultivar	Age of plants (weeks)	B/N >2 (no scales)	Scales and (B/N < 2)	Scales and (B/N > 2)	No scales and (B/N < 2)	Total
			Number of plants				
5	Ia 42 B	13	0	0	0	5	5
		14	0	1	0	4	5
		15	1	0	2	2	5
	B 2190 B	14	0	0	0	20	20
		15	4	1	8	7	20
		16	0	6	14	0	20
	B 1288 B	13	1	0	0	4	5
		14	0	2	0	3	5
		15	0	0	5	0	5
	Australian Brown	13	0	0	0	5	5
		14	0	1	0	4	5
		15	0	3	0	2	5
		16	0	1	4	0	5
	Ia 2997 B	14	0	0	0	5	5
		15	0	0	0	5	5
		16	0	2	2	1	5
	B 2215	14	1	0	0	4	5
		15	1	1	2	1	5
		16	0	2	2	1	5

Table iii (cont.)

Experiment	Cultivar	Age of plants (weeks)	Number of plants: B/N >2 (no scales)	Scales and (B/N < 2)	Scales and (B/N > 2)	No scales and (B/N < 2)	Total
5	Southport White Globe	13	0	0	0	10	10
		14	1	1	0	23	25
		15	1	13	2	9	25
	1900 B	14	1	0	0	4	5
		15	0	1	0	4	5
		16	0	2	3	0	5
	B 5546 B	14	0	0	0	5	5
		15	0	2	0	3	5
		16	0	4	1	0	5
	B 2108 B	14	0	0	0	5	5
		15	1	1	2	1	5
		16	0	0	5	0	5
	(2264 A x Colorado 6) x Colorado 6	14	0	0	0	20	20
		15	6	0	2	12	20
		16	1	6	7	6	20
	Ia 42 A x Colorado 6	14	0	0	0	20	20
		15	0	1	2	17	20
		16	0	5	14	1	20
	B 2108 A x Ia 2997 B	14	1	0	0	4	5
		15	0	0	5	0	5
		16	0	0	5	0	5

Table iv. Bulb initiation symptoms in field grown plants, Fort Collins, 1968 (Experiment 3). Means from six plants.

Cultivar	Plant age (weeks)	B/N ratio	No. scales	No. visible leaves	Leaves with maximum ratios		Youngest visible leaf		Bulbing plants (with MXLR $\leq$ 10)
					MXLR	Sheath length (cm)	YVLR	Sheath length (cm)	
1. P54 - 306 B	9	1.40	0	2.7	22.8	.16	19.2	.63	0
	10	1.31	0	4.2	32.2	.26	31.0	.26	0
	11	1.36	0	4.8	35.2	.25	35.2	.25	0
	12	1.36	0	6.2	31.2	.31	30.8	.31	0
	13	1.29	0	6.5	25.8	.22	25.8	.22	0
	14	1.27	0	8.2	28.0	.45	28.0	.45	0
	15	1.48	0	9.2	20.9	.45	20.9*	.67	0
	16	1.69	1.00	9.7	13.3	1.90	13.3	1.90	3
2. White Ebenezer	9	1.37	0	2.8	25.1	.20	24.1	.35	0
	10	1.38	0	3.7	31.8	.31	28.1	.68	0
	11	1.29	0	4.8	35.1	.31	35.1	.31	0
	12	1.38	0	5.8	33.9	.25	33.9	.25	0
	13	1.36	0	6.5	29.2	.19	28.4	.27	0
	14	1.45	0	7.7	35.1	.35	34.3	.35	0
	15	1.62	0.67	8.0	22.5	.67	22.5*	.67	1
	16	1.98	1.50	8.7	18.4	2.01	18.4	2.01	2
3. White Sweet Spanish	9	1.33	0	2.7	27.3	.18	27.3	.18	0
	10	1.32	0	3.5	38.5	.25	37.3	.25	0
	11	1.35	0	4.8	32.8	.22	31.7	.22	0
	12	1.31	0	5.8	41.2	.24	41.2	.24	0
	13	1.27	0	6.0	35.5	.17	25.6	.17	0

Table iv (cont.)

Cultivar	Plant age (weeks)	B/N ratio	No. scales	No. visible leaves	Leaves with maximum ratios: MXLR	Leaves with maximum ratios: Sheath length (cm)	Youngest visible leaf: YVLR	Youngest visible leaf: Sheath length (cm)	Bulbing plants (with MXLR ≤ 10)
White Sweet Spanish (cont.)	14	1.45	0	7.8	35.2	.32	34.4	.55	0
	15	1.54	0	8.3	24.8	.55	23.0*	.67	0
	16	2.01	0.33	8.7	15.3	1.33	15.3	1.33	2
4. Ia 42 B	9	1.40	0	2.5	21.0	.22	14.0	.90	0
	10	1.43	0	4.3	25.5	.27	25.5	.27	0
	11	1.38	0	5.2	26.7	.37	26.7	.37	0
	12	1.48	0	5.5	29.7	.26	29.3	.33	0
	13	1.38	0	6.5	26.5	.21	26.5*	.21	0
	14	1.73	0.33	7.8	22.3	.54	22.3	.54	0
	15	1.68	1.00	7.5	18.3	.94	18.3	.94	3
	16	1.83	1.17	9.3	10.8	1.51	10.8	1.51	3
5. B 2190 B	9	1.33	0	2.5	25.6	.16	16.5	1.17	0
	10	1.35	0	3.8	31.0	.27	30.8	.35	0
	11	1.32	0	5.0	29.5	.31	26.7	.37	0
	12	1.31	0	5.5	33.4	.34	32.9	.50	0
	13	1.42	0	6.5	22.3	.37	20.5	.37	0
	14	1.43	0	7.0	25.0	.46	23.4	.63	0
	15	1.73	0.83	8.2	18.0	1.12	17.4*	1.23	3
	16	2.19	1.83	9.8	8.9	2.50	7.3	2.50	5

Table iv (cont.)

Cultivar	Plant age (weeks)	B/N ratio	No. scales	No. visible leaves	Leaves with maximum ratios: MXLR	Leaves with maximum ratios: Sheath length (cm)	Youngest visible leaf: YVLR	Youngest visible leaf: Sheath length (cm)	Bulbing plants (with MXLR ≤ 10)
6. White Portugal	9	1.35	0	3.0	25.6	.25	23.9	.37	0
	10	1.25	0	4.2	30.8	.24	30.5	.61	0
	11	1.24	0	5.0	31.0	.29	30.8	.40	0
	12	1.38	0	5.7	31.3	.35	29.4	.35	0
	13	1.37	0	6.5	35.6	.35	29.8	.53	0
	14	1.38	0.33	8.2	33.1	.41	30.2	.41	0
	15	1.47	0.50	9.2	31.9	.47	31.5	.47	0
	16	1.84	1.17	9.3	26.9	1.45	26.4	1.45	1
7. B 12115 - 2	9	1.28	0	2.7	26.6	.17	21.5	.63	0
	10	1.22	0	4.0	36.8	.18	36.8	.18	0
	11	1.31	0	5.0	38.4	.30	36.7	.30	0
	12	1.20	0	5.8	35.7	.27	33.7	.27	0
	13	1.25	0	7.0	33.7	.28	33.7	.28	0
	14	1.31	0	7.7	34.9	.33	33.6*	.33	0
	15	1.44	0.67	9.0	24.8	.93	22.8	.93	1
	16	1.67	1.33	8.3	19.7	2.08	18.7	2.08	1

Table v. Effects of night interruption for two weeks by incandescent light for one hour nightly at midnight, on bulb initiation symptoms in the hybrid 'B 2190 A x Colorado 6' (Experiment 6). Means are based on six plants.

					Leaves with MXLR		Youngest visible leaf			
Plant age when treatment began	Plant age (weeks)	B/N ratio	No. scales	No. visible leaves	MXLR	Sheath length (cm)	YVLR	Sheath length (cm)	Plant height (cm)	Bulbing plants (with MXLR $\leq$ 10)
Control	8	1.19	0	2.2	33.3	.18	29.7	.57	19.1	0
	9	1.35	0	2.8	34.0	.19	33.9	.30	22.4	0
	10	1.34	0	3.7	26.6	.30	25.7	.59	27.3	0
	11	1.28	0	4.8	33.1	.27	32.8	.36	30.4	0
	12	1.21	0	5.7	43.3	.19	38.8	.39	37.2	0
	13	1.33	0	6.8	44.8	.30	44.8	.30	35.8	0
	14	1.43	0	8.7	41.7	.28	41.6	.34	46.5	0
	15	1.32	0	10.0	39.2	.34	42.3	.43	53.8	0
	16	1.45	0	10.3	35.0	.56	35.0*	.56	57.8	0
	17	1.66	0	11.2	22.2	1.08	20.8	1.90	65.1	.50
	18	1.75	0.67	12.2	17.6	1.70	17.6	1.90	64.4	.50
Four weeks	8	1.29	0	2.7	33.8	.17	33.8	.17	18.3	0
	9	1.42	0	3.2	35.5	.29	35.5	.29	23.0	0
	10	1.32	0	4.3	43.2	.17	40.3	.22	29.7	0
	11	1.42	0	4.8	38.2	.28	36.3	.37	30.5	0
	12	1.40	0	7.0	53.5	.22	52.7	.27	40.4	0
	13	1.37	0	7.2	45.2	.37	45.2	.37	42.1	0
	14	1.38	0	8.8	49.7	.17	48.6	.32	50.3	0
	15	1.37	0	10.0	34.2	.43	33.4*	.56	52.1	0
	16	1.39	0	10.2	32.7	.43	31.8	.65	53.7	0
	17	1.57	0	12.2	23.4	.89	23.4	.89	59.6	0
	18	1.63	0	13.7	28.1	.67	26.7	.80	59.9	0

Table v (cont.)

Plant age when treatment began	Plant age (weeks)	B/N ratio	No. scales	No. visible leaves	Leaves with MXLR		Youngest visible leaf		Plant height (cm)	Bulbing plants (with MXLR ≤ 10)
					MXLR	Sheath length (cm)	YVLR	Sheath length (cm)		
Six weeks	8	1.34	0	2.0	30.9	.25	29.2	.48	17.4	0
	9	1.59	0	3.0	24.7	.21	20.8	.97	19.5	0
	10	1.20	0	4.0	39.0	.18	37.0	.35	28.5	0
	11	1.36	0	5.0	36.1	.22	36.1	.22	29.2	0
	12	1.38	0	5.8	36.3	.22	46.3	.22	33.4	0
	13	1.41	0	7.5	42.2	.24	40.6	.33	40.2	0
	14	1.42	0	9.0	47.8	.29	46.8	.37	51.1	0
	15	1.41	0	9.5	41.6	.37	38.1*	.61	53.1	0
	16	1.46	0	11.0	31.1	.52	30.2	.71	60.5	0
	17	1.79	0.67	11.8	17.3	1.72	17.3	1.72	61.4	1.00
	18	1.85	0.83	11.7	13.5	3.08	13.2	3.30	66.8	1.50
Eight weeks	8	1.32	0	2.3	32.4	.20	27.1	.61	20.9	0
	9	1.15	0	3.3	36.0	.19	35.1	.34	26.5	0
	10	1.28	0	4.2	38.1	.28	37.2	.35	29.0	0
	11	1.42	0	5.0	37.3	.29	36.2	.24	29.9	0
	12	1.36	0	6.2	48.4	.24	46.4	.36	41.2	0
	13	1.52	0	7.3	30.4	.39	28.2	.67	45.5	0
	14	1.47	0	8.8	38.9	.23	35.4	.81	46.6	0
	15	1.53	0	9.7	40.5	.27	34.7	.80	49.9	0
	16	1.40	0	11.2	36.3	.46	35.2	.60	58.2	0
	17	1.61	0.50	12.5	33.6	1.17	33.6*	1.17	62.9	.50
	18	1.89	2.17	12.7	19.4	3.17	19.3	3.24	61.3	1.50

Table v (cont.)

Plant age when treatment began	Plant age (weeks)	B/N ratio	No. scales	No. visible leaves	Leaves with MXLR: MXLR	Leaves with MXLR: Sheath length (cm)	Youngest visible leaf: YVLR	Youngest visible leaf: Sheath length (cm)	Plant height (cm)	Bulbing plants (with MXLR ≤10)
Ten weeks	8	1.22	0	2.8	28.5	.26	28.5	.26	20.1	0
	9	1.32	0	3.0	31.2	.20	30.3	.44	21.2	0
	10	1.21	0	3.7	46.1	.22	46.1	.22	28.3	0
	11	1.22	0	4.5	52.4	.28	52.4	.28	33.3	0
	12	1.27	0	6.3	48.4	.23	48.4	.23	44.6	0
	13	1.40	0	7.7	42.2	.27	40.4*	.35	43.8	0
	14	1.33	0	8.2	41.0	.27	40.2	.42	46.2	0
	15	1.43	0	10.2	46.5	.37	46.5	.37	52.5	0
	16	1.77	0.50	11.3	27.8	1.80	26.9	2.32	53.8	.50
	17	1.67	0.50	11.8	16.9	1.71	16.7	1.81	54.2	.50
	18	2.04	1.67	12.0	12.3	4.84	12.3	4.84	56.6	1.50
Twelve weeks	8	1.22	0	2.2	26.6	.30	18.6	.98	20.3	0
	9	1.28	0	2.8	30.6	.23	31.2	.29	21.0	0
	10	1.23	0	3.7	42.4	.27	42.4	.27	26.6	0
	11	1.29	0	4.8	33.3	.28	33.3	.28	28.6	0
	12	1.33	0	6.2	49.2	.22	49.2	.22	36.8	0
	13	1.45	0	7.7	42.5	.28	41.1*	.36	40.8	0
	14	1.46	0	8.8	40.2	.38	40.2	.38	47.1	0
	15	1.38	0	9.8	33.6	.45	32.1	.59	49.6	0
	16	1.61	0.17	10.5	22.0	.77	19.1	2.19	48.2	0
	17	1.92	1.67	11.8	13.3	2.63	13.3	2.63	59.5	2.00
	18	2.54	2.67	12.7	10.5	4.57	10.5	4.57	59.6	2.00

Table v (cont.)

Plant age when treat-ment began	Plant age (weeks)	B/N ratio	No. scales	No. visible leaves	Leaves with MXLR		Youngest visible leaf		Plant height (cm)	Bulb-ing plants (with MXLR ≤ 10)
					MXLR	Sheath length (cm)	YVLR	Sheath length (cm)		
Continuous	8	1.50	0	2.0	18.6	.12	10.7	1.83	18.7	0
	9	1.60	0	3.0	17.6	.38	17.5	.50	23.0	0
	10	1.33	0	4.0	27.9	.21	26.0	.53	21.3	0
	11	1.25	0	5.2	40.6	.24	39.9	.30	26.3	0
	12	1.27	0	5.5	40.6	.26	37.8	.52	33.3	0
	13	1.36	0	7.3	46.4	.28	46.3	.37	42.2	0
	14	1.28	0	7.8	44.6	.23	36.6*	.56	44.6	0
	15	1.44	0	8.8	26.5	.47	24.3	.90	51.5	0
	16	1.83	1.00	9.3	12.6	2.92	12.6	2.92	50.2	1.50
	17	2.56	2.67	10.7	5.2	6.48	5.2	6.48	57.2	3.00
	18	2.98	4.83	11.0	4.2	7.55	4.2	7.55	60.4	3.00
Ages X Treatments		Sig.[2]	Sig.[2]	n.s.[1]	Sig.[2]	Sig.[2]	Sig.[2]	Sig.[2]	n.s.[1]	Sig.[2]

[1] Statistically non significant.

[2] " significant.

Table vi. Effects of planting date and temperature on bulb initiation in the hybrid 'B 2190 A x Colorado 6' (Experiment 7). Temperature differences were obtained by growing inside and outside greenhouse. Means are based on six plants.

Planting date and location	Sample date	Plant age (weeks)	B/N ratio	No. scales	No. visible leaves	Leaves with MXLR: MXLR	Leaves with MXLR: Sheath length (cm)	Youngest visible leaf: YVLR	Youngest visible leaf: Sheath length (cm)	Plant height (cm)	Bulbing plants (with MXLR ≤ 10)
April 17, 1969 greenhouse	May 29	6	1.21	0	3.3	30.1	.21	27.0	.40	27.0	0
	June 19	9	1.38	0	5.8	35.2	.31	28.3	1.12	45.3	0
	26	10	1.51	0	7.3	34.7	.38	31.9	.65	49.5	0
	July 3	11	2.22	0.83	7.0	16.9	1.88	16.2*	2.47	47.4	1.00
	12	12	2.23	1.50	7.8	15.5	2.18	13.3	2.63	51.3	1.00
	18	13	2.79	1.83	8.0	10.4	3.10	8.2	4.10	50.1	1.50
	25	14	2.49	3.17	9.2	9.7	4.28	9.7	4.28	49.1	2.00
May 2, 1969 greenhouse	May 29	4	1.14	0	2.0	33.5	.25	33.5	.25	16.6	0
	June 19	7	1.19	0	4.5	39.8	.26	39.8	.26	31.2	0
	26	8	1.31	0	6.2	41.8	.27	41.8	.27	38.2	0
	July 3	9	1.45	0	6.0	32.9	.43	32.3*	.51	44.4	0
	12	10	1.75	0	6.8	25.1	.54	25.0	.65	51.6	0
	18	11	1.85	0.50	8.3	22.8	.70	22.8	.70	51.7	.50
	25	12	2.29	3.33	8.3	14.9	4.74	14.9	4.74	58.3	2.00
April 17, 1969 outdoors	May 29	6	1.21	0	2.0	27.3	.19	27.3	.19	13.3	0
	June 19	9	1.24	0	4.0	32.0	.32	32.0	.32	25.4	0
	26	10	1.51	0	5.2	36.5	.30	35.1	.30	31.4	0
	July 3	11	1.52	0	5.8	37.3	.23	36.3	.31	39.6	0
	12	12	1.90	0	6.3	29.8	.55	29.8*	.55	39.3	0
	18	13	1.81	0	7.7	29.1	.39	29.1	.39	40.8	0
	25	14	1.89	0.33	9.0	20.0	.66	19.3	.73	41.1	0

Table vi (cont.)

Planting date and location	Sample date	Plant age (weeks)	B/N ratio	No. scales	No. visible leaves	Leaves with MXLR		Youngest visible leaf		Plant height (cm)	Bulbing plants (with MXLR $\leq$ 10)
						MXLR	Sheath length (cm)	YVLR	Sheath length (cm)		
May 2,	May 29	4	1.28	0	1.0	27.2	.24	27.2	.24	7.4	0
1969	June 19	7	1.23	0	2.8	28.5	.19	28.4	.19	16.3	0
outdoors	26	8	1.57	0	3.8	33.0	.22	33.0	.22	22.1	0
	July 3	9	1.45	0	4.7	40.1	.22	40.1	.22	26.7	0
	12	10	1.57	0	5.2	34.5	.27	32.6*	.34	31.6	0
	18	11	1.60	0	7.2	31.7	.36	31.7	.36	37.8	0
	25	12	1.78	0.17	8.2	26.1	.59	26.1	.59	43.5	0
May 2,	May 29	4	1.35	0	1.3	23.2	.14	18.8	.59	10.9	0
1969	June 19	7	1.30	0	3.7	32.3	.26	31.2	.32	21.5	0
greenhouse	26	8	1.50	0	4.3	34.4	.21	33.3	.26	24.1	0
for 10 days	July 3	9	1.55	0	5.5	44.1	.20	44.1	.20	30.2	0
then out-	12	10	1.65	0	6.3	33.1	.21	33.1	.21	38.0	0
doors	18	11	1.58	0	7.3	36.4	.30	36.4	.30	42.0	0
	25	12	1.79	0	8.0	25.8	.48	25.9	.48	47.6	0

Table vii. Bulb initiation symptoms in greenhouse grown plants, Fort Collins, 1967 (Experiment 1). Means from six plants.

Cultivar	Plant age (weeks)	B/N ratio	No. scales	No. visible leaves	EMNLR	Leaves with maximum ratios: MXLR	Leaves with maximum ratios: Sheath length (cm)	Youngest visible leaf: YVLR	Youngest visible leaf: Sheath length (cm)	Bulbing plants ($MXLR \leq 10$)
1. 8875	3	1.16	0	3.0	2.5	26.2	.16	26.2	.16	0
	4	1.50	0.17	2.8	4.4	20.2	.78	17.7*	1.40	2
	5	1.63	1.17	4.7	3.7	13.0	1.82	10.6	2.14	4
	6	2.64	2.17	5.7	3.6	5.1	3.45	5.1	3.45	5
2. 1288 A	3	1.14	0	3.0	3.6	13.4	.67	13.4	.67	1
	4	1.40	1.33	3.3	3.5	11.9	1.69	11.9*	2.02	3
	5	1.58	2.50	4.1	3.0	5.0	3.08	5.0	3.08	6
	6	3.56	3.67	5.3	3.0	3.1	2.75	3.1	2.75	6
3. 1288 x 8875	3	1.08	0	3.0	3.2	21.2	.29	21.2	.29	0
	4	1.99	0.83	3.5	3.8	13.6	1.38	13.6*	1.38	3
	5	2.99	2.17	4.8	3.5	11.5	2.28	11.5	2.28	3
	6	2.72	3.50	5.8	3.3	3.1	5.58	3.1	5.58	6
4. Colorado 761	3	1.18	0	2.5	2.2	23.4	.16	18.8	1.09	0
	4	1.33	0	3.5	3.0	24.6	.18	24.6	1.11	0
	5	1.29	0	4.8	3.0	28.3	.18	20.7*	2.09	0
	6	1.59	0	6.2	2.8	21.5	.38	16.0	.70	0
5. Ia 2997 A	3	1.07	0	3.0	2.8	21.5	.19	21.5	.19	0
	4	1.26	0.17	3.8	4.1	15.8	.75	15.8*	.75	0
	5	1.38	1.17	5.2	3.3	10.6	1.36	8.7	1.93	3
	6	2.52	3.50	5.8	3.3	3.3	5.57	3.3	5.57	6

Table vii (cont.)

Cultivar	Plant age (weeks)	B/N ratio	No. scales	No. visible leaves	EMNLR	Leaves with maximum ratios: MXLR	Leaves with maximum ratios: Sheath length (cm)	Youngest visible leaf: YVLR	Youngest visible leaf: Sheath length (cm)	Bulbing plants (MXLR ≤ 10)
6. 2997 A x	3	1.24	0	3.0	2.9	25.4	.20	25.4	.20	0
Colorado 761	4	1.22	0	3.5	3.6	17.1	.29	14.0*	1.72	2
	5	1.45	0.17	4.7	3.3	21.1	1.01	13.3	3.34	1
	6	2.02	2.17	6.0	3.1	8.5	3.35	6.4	4.08	3
7. B 2190 B	3	1.11	0	2.8	2.6	27.6	.16	24.9	.47	0
	4	1.25	0.50	3.3	3.7	18.0	1.12	16.1*	1.82	2
	5	1.66	1.67	4.5	3.4	10.5	2.38	10.5	2.38	3
	6	2.25	3.50	4.0	2.6	3.5	6.03	3.5	6.03	6
8. 1900 A	3	1.08	0	2.8	2.7	27.6	.17	25.0	.65	0
	4	1.20	0.16	3.0	3.6	14.9	.83	9.7*	1.98	1
	5	1.32	0.50	4.5	3.5	11.9	1.28	9.7	2.48	2
	6	2.97	3.67	5.3	3.5	3.1	5.47	3.1	5.47	6
9. 1900 A x	3	1.16	0	2.3	2.7	26.4	.13	20.1	1.66	0
B 2190 B	4	1.22	0.33	3.5	3.5	22.2	.54	17.3*	.93	2
	5	1.58	1.17	4.7	3.2	13.7	2.11	11.2	3.12	3
	6	3.03	4.00	5.5	3.1	3.1	7.12	3.1	7.12	6
10. 1900 A x	3	1.19	0	2.8	2.9	26.8	.21	23.2	.74	0
Colorado 6	4	1.20	0	3.8	3.8	28.2	.24	26.5	.56	0
	5	1.23	0.50	5.3	3.4	21.0	.85	18.5*	1.28	1
	6	2.02	2.33	6.0	3.6	8.1	4.57	8.1	4.57	4

Table vii (cont.)

Cultivar	Plant age (weeks)	B/N ratio	No. scales	No. visible leaves	EMNLR	Leaves with maximum ratios: MXLR	Leaves with maximum ratios: Sheath length (cm)	Youngest visible leaf: YVLR	Youngest visible leaf: Sheath length (cm)	Bulbing plants (MXLR $\leq$ 10)
11. Colorado 6	3	1.16	0	2.8	2.8	25.7	.18	23.6	.66	0
	4	1.57	0.67	3.0	3.8	17.3	1.10	9.0	2.82	3
	5	1.51	0.33	4.0	3.4	20.5	.85	18.4	1.17	1
	6	2.01	1.67	5.3	3.3	15.5	2.80	15.5	2.80	3

Table viii. Bulb initiation symptoms in field grown plants, Fort Lupton, 1969 (Experiment 5). Means from five plants.

Cultivar	Plant age (weeks)	B/N ratio	No. scales	No. visible leaves	Sheath length (cm) of leaves with MXLR	Youngest visible leaf: YVLR	Youngest visible leaf: Sheath length (cm)	Bulbing plants (MXLR ≤ 10)
1. P54 - 306 B	12	1.22	0	7.6	.27	29.0	.27	0
	13	1.30	0	9.4	.48	29.7	.48	0
	14	1.35	0	10.2	.47	30.8	.47	0
	15	1.52	0	10.8	1.84	13.6*	1.84	1
	16	1.84	0.80	13.2	2.72	6.9	2.72	4
	18	2.34	1.80	13.4	6.10	3.6	6.10	5
2. White Ebenezer	12	1.37	0	6.6	.41	32.0	.41	0
	13	1.62	0.60	8.2	.82	23.4*	.82	1
	14	1.69	0.60	9.6	1.91	11.3	1.91	2
	15	1.78	3.80	11.0	2.76	8.5	3.42	3
	16	2.07	11.20	11.6	7.10	3.5	7.10	5
	18	3.54	13.40	10.2	12.28	2.6	12.28	5
3. White Sweet Spanish	12	1.23	0	7.0	.30	39.3	.30	0
	13	1.35	0	7.8	.48	34.0*	.48	0
	14	1.38	0	.92	.59	31.1	.59	0
	15	1.41	0	10.2	.91	20.9	.91	0
	16	1.81	0.60	12.0	2.00	14.1	2.00	3
	18	2.13	9.20	16.4	8.68	3.6	8.68	5

Table viii (cont.)

Cultivar	Plant age (weeks)	B/N ratio	No. scales	No. visible leaves	Sheath length (cm) of leaves with MXLR	Youngest visible leaf: YVLR	Youngest visible leaf: Sheath length (cm)	Bulbing plants (MXLR $\leq$ 10)
4. Ia 42 B	12	1.43	0	6.4	.36	25.9	.36	0
	13	1.64	0	8.2	.40	14.8*	.48	0
	14	1.48	0.20	9.2	.88	19.0	.88	1
	15	2.04	0.80	10.0	1.92	9.0	1.92	4
	16	2.47	7.00	10.4	5.72	3.7	5.72	5
	18	2.48	7.60	11.6	6.82	4.7	6.82	4
5. B 2190 B	12	1.23	0	6.0	.30	28.4	.30	0
	13	1.52	0	8.2	.46	22.8[1]*	.46	0
	14	1.60[1]	0[1]	9.5[1]	.81[1]	19.8[1]	.94[1]	1
	15	1.96[1]	0.95[1]	10.2[1]	2.81[1]	8.3[1]	2.85[1]	16
	16	2.12[1]	5.00[1]	11.5[1]	5.17[1]	4.5[1]	5.17[1]	20
	18	2.79[1]	8.75[1]	11.5[1]	8.90[1]	3.1[1]	8.90[1]	20
6. B 1288 B	12	1.32	0	7.0	.52	23.6	.52	0
	13	1.47	0	7.6	1.11	15.7*	1.39	1
	14	1.79	0.60	8.4	2.49	6.7	3.26	4
	15	2.60	5.80	8.6	10.56	2.7	10.56	5
	16	2.85	7.40	9.6	9.78	2.5	9.78	5
	18	3.79	8.20	9.8	10.30	2.3	10.30	5
7. Australian Brown	12	1.36	0	6.8	.34	30.7	.34	0
	13	1.37	0	8.8	.51	29.4*	.51	0
	14	1.52	0.20	10.8	1.45	19.3	1.45	1
	15	1.90	3.60	10.4	4.86	7.6	4.86	3

Table viii (cont.)

Cultivar	Plant age (weeks)	B/N ratio	No. scales	No. visible leaves	Sheath length (cm) of leaves with MXLR	Youngest visible leaf: YVLR	Youngest visible leaf: Sheath length (cm)	Bulbing plants (MXLR ≤ 10)
Australian Brown (cont.)	16	2.12	11.60	13.4	7.56	4.4	7.56	5
	18	2.53	15.20	15.8	10.30	3.2	10.30	5
8. Ia 2997 B	12	1.15	0	7.0	.25	24.7	.25	0
	13	1.47	0	8.4	.53	23.7	.53	0
	14	1.48	0	9.0	.48	26.5	.61	0
	15	1.74	0	10.0	.86	15.7*	.86	0
	16	1.90	1.60	10.8	1.48	9.8	1.48	2
	18	2.04	4.40	14.0	4.68	5.7	4.68	4
9. B 2215	12	1.37	0	6.6	.38	34.8	.38	0
	13	1.48	0	8.2	.48	26.0*	.48	0
	14	1.70	0	8.4	.52	21.6	1.06	1
	15	2.02	1.60	9.6	2.66	8.3	3.12	3
	16	1.96	5.40	10.8	4.38	6.9	4.38	4
10. Southport White Globe	12	1.38	0	7.8	.40	30.9	.40	0
	13	1.56	0	9.0	.49	23.2*	.59	0
	14	1.55	0.60	9.2	1.16	13.2	2.28	2
	15	1.70	1.00	8.0	2.24	10.5	2.24	1
	16	2.05	6.20	12.1	4.84	4.5	4.84	5
	18	2.66	9.60	12.6	9.60	2.9	9.60	5

Table viii (cont.)

Cultivar	Plant age (weeks)	B/N ratio	No. scales	No. visible leaves	Sheath length (cm) of leaves with MXLR	Youngest visible leaf: YVLR	Youngest visible leaf: Sheath length (cm)	Bulb-ing plants (MXLR ≤ 10)
11. 1900 B	12	1.28	0	6.8	.26	33.8	.26	0
	13	1.53	0	7.8	.44	27.6	.44	0
	14	1.46	0	7.8	.79	27.9	.87	1
	15	1.65	0.80	8.2	1.66	11.7*	1.66	2
	16	1.97	6.80	10.8	5.58	4.7	5.58	5
	18	3.15	9.60	9.8	11.92	3.0	11.92	5
12. B 5546 B	12	1.28	0	7.4	.34	31.3	.34	0
	13	1.40	0	8.8	.70	20.6*	.70	0
	14	1.52	0	10.4	1.19	15.8	1.39	0
	15	1.76	1.00	11.8	2.46	6.1	3.52	4
	16	1.81	2.60	13.6	1.80	6.6	2.80	4
	18	2.71	8.60	14.4	11.20	2.9	11.20	5
13. B 2108 B	12	1.32	0	7.0	.25	35.9	.25	0
	13	1.52	0	8.6	.55	21.3*	.55	0
	14	1.58	0	10.0	.74	13.5	1.42	1
	15	1.96	1.00	11.2	2.52	6.4	2.92	4
	16	2.25	6.40	14.2	4.20	3.8	4.20	5
	18	2.93	12.20	12.2	8.40	2.6	8.40	5

Table viii (cont.)

Cultivar	Plant age (weeks)	B/N ratio	No. scales	No. visible leaves	Sheath length (cm) of leaves with MXLR	Youngest visible leaf: YVLR	Youngest visible leaf: Sheath length (cm)	Bulbing plants (MXLR ≤ 10)
14. B. C. (B 2264 x Colo. 6) x Colo. 6	12	1.22	0	8.2	.38	32.1	.38	0
	13	1.41	0	8.6	.62	23.7	.62	0
	14	1.50[1]	0[1]	9.6[1]	.60[1]	29.2[1]	.67[1]	0
	15	1.82[1]	0.50[1]	11.7[1]	2.04[1]	11.9[1]*	2.38[1]	8
	16	2.00[1]	2.60[1]	5.1[1]	4.73[1]	5.4[1]	4.73[1]	20
	18	2.59[1]	3.25[1]	17.0[1]	7.69[1]	3.8[1]	7.69[1]	20
15. Ia 42 A x Colo. 6	12	1.27	0	8.0	.26	31.7	.26	0
	13	1.44	0	8.8	.59	20.6	.59	0
	14	1.47[1]	0[1]	9.5[1]	.56[1]	24.7[1]	.62[1]	0
	15	1.70[1]	0.30[1]	11.8[1]	1.70[1]	12.3[1]*	1.77[1]	4
	16	2.09[1]	5.85[1]	14.0[1]	5.15[1]	5.0[1]	5.15[1]	20
	18	2.75[1]	12.90[1]	15.0[1]	11.75[1]	2.4[1]	11.75[1]	20
16. B 2108 A x Ia 2997 B	12	1.36	0	8.4	.25	32.2	.25	0
	13	1.66	0	8.8	.60	17.9*	.60	0
	14	1.77	0	10.4	1.00	12.5	1.00	0
	15	2.31	2.00	12.0	3.86	4.6	4.62	5
	16	2.68	10.40	15.2	7.18	3.2	7.18	5
	18	3.79	12.00	13.0	9.98	2.2	9.98	5

[1] Means for 20 plants

Table ix. Bulb initiation symptoms in greenhouse grown plants, Fort Collins, 1967 (Experiment 2). Means from six plants.

Cultivar	Plant age (weeks)	B/N ratio	No. scales	No. visible leaves	EMNLR	Leaves with maximum ratios		Youngest visible leaf		Bulbing plants (MXLR ≤ 10)
						MXLR	Sheath length (cm)	YVLR	Sheath length (cm)	
1. Early White Mexican	3	1.57	0.30	3.0	2.2	4.8	2.40	4.8	2.40	6
	4	2.41	1.20	4.0	2.8	8.1	2.23	8.1	2.23	4
	5	5.04	2.50	4.5	3.8	3.0	3.60	3.0	3.60	6
2. Australian Brown	3	1.23	0	3.0	3.0	19.0	.89	19.0	.89	2
	4	2.35	0.83	3.5	6.4	8.2	1.80	8.2*	1.80	4
	5	2.21	1.50	4.5	4.8	5.9	1.88	5.9	1.88	6
3. Red Creole	3	1.44	0.60	3.0	2.8	7.3	1.32	7.3	1.32	4
	4	4.16	2.00	3.0	---	4.0	3.10	4.0	3.10	6
	5	5.20	2.70	3.0	---	4.5	2.72	4.5	2.72	5
4. Yellow Ebenezer	3	1.12	0	3.0	2.6	21.8	.77	9.5	1.40	1
	4	1.97	0.83	4.0	4.6	11.2	1.11	10.4	1.45	4
	5	2.49	1.20	4.6	4.1	9.5	1.10	9.5	1.28	2
5. Southport White Globe	3	1.24	0	3.0	2.3	21.9	.29	17.1	1.02	0
	4	1.31	0.80	4.0	4.2	12.7	.96	8.5*	1.78	2
	5	2.39	2.00	4.8	3.1	5.8	2.77	5.8	2.77	5
6. White Portugal	3	1.45	0.15	3.2	3.0	16.6	.47	12.5	1.37	1
	4	1.48	0.65	4.2	4.1	15.7	1.55	7.5	2.13	2
	5	2.01	1.35	4.4	3.5	9.3	2.09	9.3	2.09	4
7. White Lisbon	3	1.28	0	3.0	2.6	18.5	.38	10.3	1.35	0
	4	1.20	0	3.7	3.6	23.7	.39	14.7	1.22	0
	5	1.94	0.65	4.8	3.1	11.0	1.58	10.6	2.04	2

Table ix (cont.)

Cultivar	Plant age (weeks)	B/N ratio	No. scales	No. visible leaves	EMNLR	Leaves with maximum ratios: MXLR	Leaves with maximum ratios: Sheath length (cm)	Youngest visible leaf: YVLR	Youngest visible leaf: Sheath length (cm)	Bulbing plants (MXLR $\leq$ 10)
8. White	3	1.32	0	3.2	2.3	12.0	.70	9.5	1.52	2
Ebenezer	4	1.74	0.65	3.7	4.0	11.4	1.43	9.4*	1.62	3
	5	2.85	2.00	4.7	4.2	4.1	3.00	4.1	3.00	6
9. Crystal	3	1.26	0	3.4	2.0	24.5	.20	17.0	1.32	0
White	4	1.64	0.50	4.0	3.6	9.1	1.57	8.6*	1.78	4
Wax	5	3.45	2.20	4.2	3.7	3.8	3.70	3.8	3.70	6
10. Excel	3	1.36	0.15	3.0	2.4	7.8	2.27	4.3	2.63	4
Bermuda	4	2.83	1.30	3.7	3.1	4.5	3.00	2.7	3.70	5
	5	3.51	2.00	3.5	3.0	2.9	4.14	2.9	4.14	5

Table x. Mean leaf sheath lengths of plants with and without scales. Eleven greenhouse grown cultivars, Fort Collins, 1967 (Experiment 1).

		Without Scales			With Scales			
			Sheath length (cm) of			Sheath length (cm) of		
Cultivar	Plant age (weeks)	No. plants	Youngest visible leaves	Leaves with MXLR	No. plants	Youngest visible leaves	Leaves with MXLR	Total no. plants
1. 8875	3	6	.16	.16	0	---	---	6
	4	5	.47	1.22	1	2.30	2.30	6
	5	3	.43	1.08	3	3.20	3.20	6
	6	1	1.90	1.90	5	3.76	3.76	6
2. 1288 A	3	6	.67	.67	0	---	---	6
	4	2	.14	2.35	4	1.86	1.86	6
	5	0	---	---	6	3.08	3.08	6
	6	0	---	---	6	2.75	2.75	6
3. 1288 x 8875	3	6	.29	.29	0	---	---	6
	4	3	.23	.23	3	1.38	1.38	6
	5	2	.50	.50	4	3.17	3.17	6
	6	0	---	---	6	5.58	5.58	6
4. Colorado 761	3	6	.16	1.09	0	---	---	6
	4	6	.18	1.11	0	---	---	6
	5	6	.18	2.09	0	---	---	6
	6	6	.38	.70	0	---	---	6
5. 2997 A	3	6	.19	.19	0	---	---	6
	4	5	.30	.30	1	3.00	3.00	6
	5	2	.47	2.20	4	1.80	1.80	6
	6	0	---	---	6	5.57	5.57	6

Table x (cont.)

Cultivar	Plant age (weeks)	Without Scales: No. plants	Without Scales: Sheath length (cm) of Youngest visible leaves	Without Scales: Sheath length (cm) of Leaves with MXLR	With Scales: No. plants	With Scales: Sheath length (cm) of Youngest visible leaves	With Scales: Sheath length (cm) of Leaves with MXLR	Total no. plants
6. 2997 A x	3	6	.20	.20	0	---	---	6
Colorado 761	4	6	.29	1.72	0	---	---	6
	5	5	.31	3.11	1	4.50	4.50	6
	6	1	.40	3.80	5	4.14	4.14	6
7. B 2190 B	3	6	.16	.47	0	---	---	6
	4	4	.20	1.25	2	2.95	2.95	6
	5	2	.90	.90	4	3.14	3.14	6
	6	0	---	---	6	6.03	6.03	6
8. 1900 A	3	6	.17	.65	0	---	---	6
	4	5	.29	1.68	1	3.50	3.50	6
	5	4	.32	1.70	2	2.70	2.70	6
	6	0	---	---	6	5.47	5.47	6
9. 1900 A x B 2190 B	3	6	.13	1.66	0	---	---	6
	4	4	.18	.77	2	1.25	1.25	6
	5	3	.35	2.38	3	3.87	3.87	6
	6	0	---	---	6	7.12	7.12	6
10. 1900 A x	3	6	.21	.74	0	---	---	6
Colorado 6	4	6	.24	.56	0	---	---	6
	5	4	.30	.94	2	1.95	1.95	6
	6	0	---	---	6	4.57	4.57	6

Table x (cont.)

	Cultivar	Plant age (weeks)	Without Scales: No. plants	Without Scales: Sheath length (cm) of Youngest visible leaves	Without Scales: Sheath length (cm) of Leaves with MXLR	With Scales: No. plants	With Scales: Sheath length (cm) of Youngest visible leaves	With Scales: Sheath length (cm) of Leaves with MXLR	Total no. plants
11.	Colorado 6	3	6	.18	.66	0	---	---	6
		4	4	.60	3.17	1	4.20	4.20	5
		5	5	.40	.79	1	3.10	3.10	6
		6	2	.35	.35	4	4.02	4.02	6

Table xi. Mean leaf sheath lengths of plants with and without scales. Ten cultivars, Fort Collins, 1967 (Experiment 2).

		Without Scales			With Scales			
			Sheath length (cm) of			Sheath length (cm) of		
Cultivar	Age of plants (weeks)	No. plants	Youngest visible leaves	Leaves with MXLR	No. plants	Youngest visible leaves	Leaves with MXLR	Total no. plants
1. Early White Mexican	3	4	2.17	2.17	2	2.85	2.85	6
	4	2	.24	.24	4	3.25	3.25	6
	5	0	---	---	6	3.60	3.60	6
2. Australian Brown	3	6	.89	.89	0	---	---	6
	4	3	.71	.71	3	2.90	2.90	6
	5	2	.57	.57	4	2.52	2.52	6
3. Red Creole	3	2	1.18	1.18	3	1.42	1.42	5
	4	0	---	---	6	3.10	3.10	6
	5	0	---	---	5	2.76	2.76	5
4. Yellow Ebenezer	3	4	.37	1.87	0	---	---	4
	4	3	.15	.84	3	2.07	2.07	6
	5	2	.36	.75	3	1.63	1.63	5
5. Southport White Globe	3	6	.29	1.02	0	---	---	6
	4	2	.11	1.50	4	1.39	1.80	6
	5	0	---	---	6	2.77	2.77	6
6. White Portugal	3	5	.19	1.26	1	1.90	1.90	6
	4	3	.06	1.25	3	3.00	3.00	6
	5	1	.45	.45	4	2.50	2.50	5

Table xi (cont.)

	Cultivar	Age of plants (weeks)	Without Scales			With Scales			Total no. plants
			No. plants	Sheath length (cm) of Youngest visible leaves	Sheath length (cm) of Leaves with MXLR	No. plants	Sheath length (cm) of Youngest visible leaves	Sheath length (cm) of Leaves with MXLR	
7.	White Lisbon	3	6	.38	1.35	0	---	---	6
		4	6	.39	1.22	0	---	---	6
		5	3	.12	1.03	3	3.05	3.05	6
8.	White Ebenezer	3	6	.70	1.52	0	---	---	6
		4	3	.22	.61	3	2.63	2.63	6
		5	0	---	---	6	3.00	3.00	6
9.	Crystal White Wax	3	5	.20	1.32	0	---	---	5
		4	3	.77	1.19	3	2.37	2.37	6
		5	0	---	---	6	3.70	3.70	6
10.	Excel Bermuda	3	5	2.22	2.66	1	2.50	2.50	6
		4	2	1.10	2.20	4	2.90	2.90	6
		5	0	---	---	5	4.14	4.14	5

Table xii. Mean sheath lengths of plants with and without scales. Seven field grown cultivars, Fort Collins, 1968 (Experiment 3).

Cultivar	Plant age (weeks)	Without Scales			With Scales			Total no. plants
		No. plants	Sheath length (cm) of Youngest visible leaves	Sheath length (cm) of Leaves with MXLR	No. plants	Sheath length (cm) of Youngest visible leaves	Sheath length (cm) of Leaves with MXLR	
1. P54 - 306 B	9	6	.16	.63	0	---	---	6
	10	6	.26	.26	0	---	---	6
	11	6	.25	.25	0	---	---	6
	12	6	.31	.31	0	---	---	6
	13	6	.22	.22	0	---	---	6
	14	6	.45	.45	0	---	---	6
	15	6	.45	.67	0	---	---	6
	16	5	1.00	1.00	1	6.40	6.40	6
2. White Ebenezer	9	6	.20	.35	0	---	---	6
	10	6	.31	.68	0	---	---	6
	11	6	.31	.31	0	---	---	6
	12	6	.25	.25	0	---	---	6
	13	6	.19	.27	0	---	---	6
	14	6	.35	.35	0	---	---	6
	15	4	.50	.50	2	1.00	1.00	6
	16	4	.45	.45	2	5.15	5.15	6
3. White Sweet Spanish	9	6	.18	.18	0	---	---	6
	10	6	.25	.48	0	---	---	6
	11	6	.22	.22	0	---	---	6
	12	6	.24	.24	0	---	---	6

Table xii (cont.)

Cultiver	Plant age (weeks)	Without Scales: No. plants	Without Scales: Sheath length (cm) of Youngest visible leaves	Without Scales: Sheath length (cm) of Leaves with MXLR	With Scales: No. plants	With Scales: Sheath length (cm) of Youngest visible leaves	With Scales: Sheath length (cm) of Leaves with MXLR	Total no. plants
3. White Sweet Spanish	13	6	.17	.17	0	---	---	6
	14	6	.32	.55	0	---	---	6
	15	6	.55	.67	0	---	---	6
	16	5	.80	.80	1	4.00	4.00	6
4. Ia 42 B	9	6	.22	.90	0	---	---	6
	10	6	.27	.27	0	---	---	6
	11	6	.37	.37	0	---	---	6
	12	6	.26	.33	0	---	---	6
	13	6	.21	.21	0	---	---	6
	14	5	.43	.43	1	1.10	1.10	6
	15	4	.46	.46	2	1.90	1.90	6
	16	3	.52	.52	3	2.50	2.50	6
5. B 2190 B	9	6	.16	1.17	0	---	---	6
	10	6	.27	.35	0	---	---	6
	11	6	.31	.37	0	---	---	6
	12	6	.34	.50	0	---	---	6
	13	6	.37	.37	0	---	---	6
	14	6	.46	.63	0	---	---	6
	15	3	.43	.43	3	1.80	1.80	6
	16	1	1.70	1.70	5	2.68	2.68	6

Table xii (cont.)

Cultivar	Plant age (weeks)	Without Scales: No. plants	Without Scales: Sheath length (cm) of Youngest visible leaves	Without Scales: Sheath length (cm) of Leaves with MXLR	With Scales: No. plants	With Scales: Sheath length (cm) of Youngest visible leaves	With Scales: Sheath length (cm) of Leaves with MXLR	Total no. plants
6. White Portugal	9	6	.25	.37	0	---	---	6
	10	6	.24	.61	0	---	---	6
	11	6	.29	.40	0	---	---	6
	12	6	.35	.35	0	---	---	6
	13	6	.35	.53	0	---	---	6
	14	5	.35	.35	1	1.00	1.00	6
	15	5	.40	.40	1	1.00	1.00	6
	16	5	.49	.49	1	5.80	5.80	6
7. B 12115 - 2	9	6	.17	.63	0	---	---	6
	10	6	.18	.18	0	---	---	6
	11	6	.30	.30	0	---	---	6
	12	6	.27	.27	0	---	---	6
	13	6	.28	.28	0	---	---	6
	14	6	.33	.33	0	---	---	6
	15	4	.39	.39	2	2.05	2.05	6
	16	4	.60	.60	2	5.05	5.05	6

Table xiii. Mean sheath lengths of plants with and without scales. Sixteen field grown cultivars, Fort Lupton, 1969 (Experiment 5).

Cultivar	Plant age (weeks)	Without Scales: No. plants	Without Scales: Sheath length (cm) of Youngest visible leaves	Without Scales: Sheath length (cm) of Leaves with MXLR	With Scales: No. plants	With Scales: Sheath length (cm) of Youngest visible leaves	With Scales: Sheath length (cm) of Leaves with MXLR	Total no. plants
1. P54 - 306 B	12	5	.27	.27	0	---	---	5
	13	5	.48	.48	0	---	---	5
	14	5	.47	.47	0	---	---	5
	15	5	1.84	1.84	0	---	---	5
	16	2	2.65	2.65	2	2.40	2.40	4
2. White Ebenezer	12	5	.41	.41	0	---	---	5
	13	4	.37	.37	1	2.60	2.60	5
	14	3	1.02	1.02	2	1.85	3.25	5
	15	0	---	---	5	2.76	3.42	5
	16	0	---	---	5	7.10	7.10	5
3. White Sweet Spanish	12	5	.30	.30	0	---	---	5
	13	5	.48	.48	0	---	---	5
	14	5	.59	.59	0	---	---	5
	15	5	.91	.91	0	---	---	5
	16	3	1.43	1.43	2	2.85	2.85	5
4. Ia 42 B	12	5	.36	.36	0	---	---	5
	13	5	.40	.48	0	---	---	5
	14	4	.72	.72	1	1.50	1.50	5
	15	3	1.20	1.70	2	2.25	2.25	5
	16	0	---	---	5	5.72	5.72	5

Table xiii (cont.)

Cultivar	Plant age (weeks)	Without Scales: No. plants	Without Scales: Sheath length (cm) of Youngest visible leaves	Without Scales: Sheath length (cm) of Leaves with MXLR	With Scales: No. plants	With Scales: Sheath length (cm) of Youngest visible leaves	With Scales: Sheath length (cm) of Leaves with MXLR	Total no. plants
5. B 2190 B	12	5	.30	.30	0	---	---	5
	13	5	.46	.46	0	---	---	5
	14	20	.81	.94	0	---	---	20
	15	11	1.99	2.16	9	3.82	3.82	20
	16	0	---	---	20	5.17	5.17	20
6. B 1288 B	12	5	.52	.52	0	---	---	5
	13	5	1.11	1.39	0	---	---	5
	14	3	1.58	2.20	2	3.85	4.85	5
	15	0	---	---	5	10.56	10.56	5
	16	0	---	---	5	9.78	9.78	5
7. Australian Brown	12	5	.34	.34	0	---	---	5
	13	5	.51	.51	0	---	---	5
	14	4	.47	.81	1	1.20	4.00	5
	15	2	1.30	1.30	3	7.23	7.23	5
	16	0	---	---	5	7.56	7.56	5
8. Ia 2997 B	12	5	.25	.25	0	---	---	5
	13	5	.53	.53	0	---	---	5
	14	5	.48	.61	0	---	---	5
	15	5	.86	.86	0	---	---	5
	16	1	1.40	1.40	4	1.50	1.50	5

Table xiii (cont.)

Cultivar	Plant age (weeks)	Without Scales: No. plants	Without Scales: Sheath length (cm) of Youngest visible leaves	Without Scales: Sheath length (cm) of Leaves with MXLR	With Scales: No. plants	With Scales: Sheath length (cm) of Youngest visible leaves	With Scales: Sheath length (cm) of Leaves with MXLR	Total no. plants
9. B 2215	12	5	.38	.38	0	---	---	5
	13	5	.48	.48	0	---	---	5
	14	5	.52	1.06	0	---	---	5
	15	2	1.80	1.80	3	3.23	4.00	5
	16	1	.70	.70	4	5.30	5.30	5
10. Southport White Globe	12	5	.40	.40	0	---	---	5
	13	5	.49	.59	0	---	---	5
	14	3	.87	.87	2	1.60	1.60	5
	15	3	1.76	1.76	2	2.95	2.95	5
	16	0	---	---	5	4.84	4.84	5
11. 1900 B	12	5	.26	.26	0	---	---	5
	13	5	.44	.44	0	---	---	5
	14	5	.79	.87	0	---	---	5
	15	4	1.35	1.35	1	2.90	2.90	5
	16	0	---	---	5	5.58	5.58	5
12. B 5546 B	12	5	.34	.34	0	---	---	5
	13	5	.70	.70	0	---	---	5
	14	5	1.19	1.39	0	---	---	5
	15	3	2.20	3.20	2	2.85	4.00	5
	16	0	---	---	5	2.80	2.80	5

Table xiii (cont.)

Cultivar	Plant age (weeks)	Without Scales: No. plants	Without Scales: Sheath length (cm) of Youngest visible leaves	Without Scales: Sheath length (cm) of Leaves with MXLR	With Scales: No. plants	With Scales: Sheath length (cm) of Youngest visible leaves	With Scales: Sheath length (cm) of Leaves with MXLR	Total no. plants
13. B 2108 B	12	5	.25	.25	0	---	---	5
	13	5	.55	.55	0	---	---	5
	14	5	.74	1.42	0	---	---	5
	15	2	2.25	3.05	3	2.83	2.83	5
	16	0	---	---	5	4.20	4.20	5
14. B. C. (B 2264 x Colo. 6) x Colorado 6	12	5	.38	.38	0	---	---	5
	13	5	.62	.62	0	---	---	5
	14	20	.60	.67	0	---	---	20
	15	18	1.42	1.94	2	6.35	6.35	20
	16	7	3.77	3.77	13	8.67	8.67	20
15. Ia 42 B x Colo. 6	12	5	.26	.26	0	---	---	5
	13	5	.59	.59	0	---	---	5
	14	20	.56	.62	0	---	---	20
	15	17	1.64	1.77	3	1.77	1.77	20
	16	1	1.60	1.60	19	5.34	5.34	20
16. B 2108 A x Ia 2997 B	12	5	.25	.25	0	---	---	5
	13	5	.60	.60	0	---	---	5
	14	5	1.00	1.00	0	---	---	5
	15	0	---	---	5	3.86	4.62	5
	16	0	---	---	5	7.18	7.18	5

Table xiv. Effects of planting date on bulb initiation symptoms in the variety 'White Portugal', field grown, Fort Collins, 1968 (Experiment 4). Mean values are based on samples of 12 plants, obtained at plant age indicated.

Planting date	Sample date	Plant age (weeks)	B/N ratio	No. scales	No. visible leaves	Leaves with maximum ratios: MXLR	Leaves with maximum ratios: Sheath length (cm)	Youngest visible leaf: YVLR	Youngest visible leaf: Sheath length (cm)	Bulbing plants (MXLR ≤ 10)
April 15	June 18	9	1.33	0	2.7	29.6	.20	25.0	.54	0
	25	10	1.24	0	4.0	29.8	.21	28.1	.41	0
	July 2	11	1.34	0	5.0	34.6	.31	34.6	.31	0
	9	12	1.33	0	5.7	38.6	.29	38.6	.29	0
	16	13	1.31	0	6.0	41.4	.31	40.7	.31	0
	23	14	1.57	.83	6.8	27.4	.90	26.6	.95	.50
	30	15	1.70	.91	7.9	28.1	1.19	27.4	1.32	.50
	Aug. 6	16	1.55	.83	9.8	20.4	1.30	18.5*	1.39	.50
	13	17	2.19	2.50	9.0	12.8	3.35	10.4	3.35	1.43
	$\bar{x}$									.32
April 22	June 18	8	1.45	0	2.5	25.3	.26	20.2	.42	0
	25	9	1.32	0	3.3	34.2	.20	32.0	.29	0
	July 2	10	1.30	0	4.2	31.2	.25	28.6	.44	0
	9	11	1.34	0	5.3	39.5	.30	39.5	.35	0
	16	12	1.33	0	6.0	47.1	.24	46.8	.29	0
	23	13	1.37	0	6.6	32.8	.41	31.9*	.49	0
	30	14	1.51	.33	7.9	29.2	.75	28.0	.75	.25
	Aug. 6	15	1.68	.75	8.4	24.2	1.27	22.6	1.48	.75
	13	16	2.04	2.00	8.4	18.3	3.19	17.4	3.23	1.00
	$\bar{x}$									.22

Table xiv (cont.)

Planting date	Sample date	Plant age (weeks)	B/N ratio	No. scales	No. visible leaves	Leaves with maximum ratios: MXLR	Leaves with maximum ratios: Sheath length (cm)	Youngest visible leaf: YVLR	Youngest visible leaf: Sheath length (cm)	Bulbing plants (MXLR ≤ 10)
April 29	June 18	7	1.10	0	2.0	21.0	.24	18.4	.69	0
	25	8	1.31	0	2.7	25.4	.21	17.9	1.06	0
	July 2	9	1.32	0	3.9	33.0	.16	27.1	.45	0
	9	10	1.24	0	4.8	35.0	.32	34.7	.35	0
	16	11	1.32	0	5.5	41.1	.28	39.9	.31	0
	23	12	1.35	.25	6.7	38.6	.34	35.6*	.35	0
	30	13	1.35	.25	7.3	36.3	.59	34.4	.64	.25
	Aug. 6	14	1.44	0	8.5	31.8	.53	31.0	.53	0
	13	15	1.82	.75	8.6	24.0	1.62	22.6	1.62	.25
	x̄									.08
May 6	June 18	6	1.24	0	2.0	24.3	.19	22.3	.39	0
	25	7	1.34	0	2.3	21.7	.16	16.7	.62	0
	July 2	8	1.28	0	3.2	26.7	.20	22.2	.65	0
	9	9	1.25	0	4.4	33.6	.23	31.5	.33	0
	16	10	1.27	0	5.5	38.9	.25	38.3	.28	0
	23	11	1.24	0	6.3	37.2	.31	35.2*	.37	0
	30	12	1.29	.25	6.3	29.8	.61	29.8	.61	.25
	Aug. 6	13	1.43	.17	8.0	31.0	.52	30.1	.52	.25
	13	14	1.84	.92	7.5	24.8	1.61	22.8	1.61	.75
	x̄									.14
L.S.D. (.05) for planting dates										.04