# A STUDY OF GERMINATION AND FLOWERING IN

# **CICHORIUM INTYBUS. L**

A thesis submitted in partial fulfillment of the requirement

for the degree of Master of Science

by

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# Preface

This study was undertaken while the author was employed as research officer at the Chicory Board at Alexandria (See frontispiece).

The author wishes to record his sincere gratitude to the following persons:

Dr R.A. Lubke, for his interest and assistance, without which this study would not have been possible.

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**Frontispiece**

Aerial view of the Chicory Board's premises - ALEXANDRIA

Systematic Classification of **Cichorium intybus L.**

| | | |
|---|---|---|
| Kingdom | : | Plantae |
| Division | : | Spermatophytae |
| Sub-division | : | Angiospermae |
| Class | : | Dicotyledonae |
| Sub-class | : | Sympetalae |
| Order | : | Asterales |
| Family | : | Asteraceae (Compositae) |
| Sub-family | : | Liguliflorae |
| Genus | : | Cichorium |
| Species | : | **Cichorium intybus L.** |

Fig. 1: **The Chicory Plant** (Poster from Dr. Weise - Austria)


KEY:

1. Taproot.
2. Vegetative growth.
3. Inflorescence Bud.
4. Capitulum.
5. Withered capitulum.
6. Cross-section through capitulum.
7. Single floret.
8. Capitulum with ripe "seeds".
9. Achene.
10. Root of improved chicory.

## 1. INTRODUCTION.

Chicory (**Cichorium intybus L**) is a deep rooted biennial (or weakly perennial) composite that is grown as an annual in South Africa for its parsnip-like root. In its wild state the plant is a perennial with thin fibrous roots, but, through selection and propagation, cultivars with large, fleshy roots have been developed. From a purely horticultural standpoint, chicory is of interest as a pot-herb, a salad plant and as a root (Bailey, 1942). As a root, the chicory plant represents an important article of commerce. In South Africa, the plants are grown virtually exclusively for their roots which, after drying, roasting and grinding, are used as an additive to, or substitute for, coffee.

After harvesting the roots are delivered to the Chicory Board at Alexandria (see Frontispiece), where they are diced into pieces of approximately 15 x 15 x 8 mm and dried at varying temperatures. Working at a capacity of 11,5 tons per hour the inlet temperatures vary from 450° - 470 °C and the outlet, between 128 - 132°C (Greyling, 1983). The main producers of dried chicory root are France, Belgium, India, South Africa and certain Eastern European countries. Coffee is not grown in economically viable quantities in South Africa, and chicory is substituted in blends from 25 - 75%. In most cases about 60% is added to coffee but pure chicory is also produced as an alternative to coffee (Weich, 1983).

Most of the chicory seed used in South Africa is imported from Europe by the Chicory Board. A programme to produce local chicory seed is in progress with positive results and it is said that South Africa will become independent of imported seed in the near future (Aucamp, 1983). The main problem in seed production is that although the Alexandria environment is suitable for the

growth of chicory, it is not suitable for seed production because the winter temperatures are too mild to stimulate flowering. Also the lack of frost, results in a predominance of various leaf-sucking insects, which would rapidly cause a build-up of the Tobacco Mosaic virus and the Spotted wilt virus, since these viruses are transmittable through the seed. It is anticipated that this problem could be overcome by systematic control of the vectors (Luckman,1984). The object of this study is to determine a method whereby seed production can be implemented in the Alexandria area in the shortest possible time. Very little work has been done on the germination of chicory, in this country, and the factors responsible for optimum germination were therefore also investigated.

## 2. THE CHICORY PLANT AND ITS PRODUCTION IN SOUTH AFRICA.

### 2.1 DESCRIPTION OF THE SPECIES.

**Cichorium intybus L** (Asteraceae): a sub-woody, erect, branched biennial (weakly perennial) which grows to a height of about 45 cm, containing milky juice, and has a stout tap root and large basal leaves. Stems striate, sparsely pubescent to glabrous, dark greyish green. Basal leaves up to 28 cm long, 10 cm broad, irregularly pinnately lobed; cauline leaves oblong-lanceolate, dentate to nearly entire, auriculate at the base, grandular-pubescent. Capitula sessile, solitary on short branches or two to four in the axils of these branches, less than 10 cm long, about 2,5 cm in diameter across and ray-florets blue. Involucral-bracts in two rows; the outer 3 mm long, oblong lanceolate, erect with a recurved apex, the inner erect, 1 cm long, linear oblong, with stalked glandular hairs at the apex, otherwise glabrous. Fruit an achene, pale brownish to black, sometimes mottled, 2 - 3 mm long, angled, glabrous, oblong, narrowed to the base, straight or slightly curved. Pappus of short, narrow brownish scales.

### 2.2 CHEMICAL COMPOSITION OF COMMERCIAL CHICORY.

Chicory contains the polyfructosan, **inulin**, as its storage carbohydrate, having glucose and fructose as the structural units (Singh and Bhatia, 1970). Upon hydrolysis, inulin yields substantial quantities of fructose and was investigated as a possible fructose crop by Haber et al (1941). Protein (5%), fat, ash, moisture, fibre and a bitter principle, **lactucopicrin**, make up the balance. The quality of the roasted product is mainly determined by the sugar content in the chicory, while the protein contributes more specifically to the aroma. The lactucopicrin, is completely destroyed during the roasting process.

## 2.3 MEDICINAL PROPERTIES OF CHICORY

The water-soluble fraction of the root contains substances which have a sedative action and antagonises the action of coffee and tea (Forest, 1940). The effect is through the central nervous system.

Scientists have declared that chicory is not only harmless to the human system, but is actually beneficial. The work of the heart is facilitated by the ingestion of chicory (Muller, 1955, in Leroux (1963)). Baeldon (1952, in Leroux (1963)) showed that an additive of chicory to coffee reduced the amplitude and acceleration of the heart-beat caused by the action of caffeine when coffee is consumed on its own. He described the action of chicory on the glycogenic function of the liver and the advantages of chicory for diabetics. The insulin of the chicory is transformed into fructose that is assimilated directly by the blood without any preceding digestion, thus making the work of the liver easier. Chicory does not contain harmful drugs nor alkaloids, its action being stimulating as it acts smoothly on the central nervous system without harming it (Winckel, 1955, in Leroux (1963)). The general influence of chicory consumption procures a physical equilibrium and a mental activity that is most satisfying (Mantoy, 1956; Vasseur, 1958, in Leroux (1963)).

## 2.4 HISTORY OF CHICORY CULTIVATION IN SOUTH AFRICA

Chicory was cultivated for the first time in the district of Alexandria in the Eastern Cape during the year 1895. It was grown for household purposes rather than for marketing, as all the chicory required for the country's consumption was imported.

In Alexandria chicory originally was cut with knives to a thickness of half an inch and it was dried in the sun on top of flat roofs or on sheets of

corrugated iron. Later, in 1910 a limited market developed in Port Elizabeth where the dried root was sold to confectionary manufacturers. The demand was unstable. It was just before the commencement of World War I that organisations became interested in chicory, and larger quantities were grown.

In 1926, the Co-operative Chicory Growers' Association of Alexandria was established. Further appeals were made to the authorities and as a result in 1931, by means of Act No. 44, the tax on "Chicory and Coffee and Chicory substitutes" and "chicory root", was increased. The wording of "chicory and coffee and chicory substitutes" was changed, the words "and coffee" being deleted.

The Chicory Control Scheme, as promulgated under Proclamation No. 335 of 1939, came into operation on 1st January 1940 after it had been voted for and accepted by growers. Its objects were to regulate the production and marketing of chicory in terms of the Marketing Act.

The Chicory Control Scheme made full provision for the control of the chicory industry which was concentrated in the districts of Alexandria, Albany and Bathurst. The Chicory Control Board originally consisted of seven chicory producers, one coffee manufacturer and one representative of the Department of Agriculture. A proclamation forbidding the sale of chicory through any channel other than the Chicory Control Board was only promulgated on the 1st April 1941.

## 2.5 HISTORY OF CHICORY SEED PRODUCTION IN SOUTH AFRICA.

The birth of the Chicory Industry in the Republic dates back to the beginning of the nineteenth century and it is presumed that the habit of mixing roasted chicory with coffee beans was brought here by the settlers from Europe. Until about 1895 all dried chicory root was imported, but around about this time local cultivation was begun by the Smith family and others in the Alexandria district of the Eastern Cape, from seed imported from Europe. Since then, all seed used in the Republic has been imported from Europe with two exceptions, namely:

(a) Firstly, during the Second World War, restrictions on importation made the procurement of seed impossible and the industry had to rely on seed produced locally in the Kaba Valley near Alexandria. The method used was to allow chicory to remain in the ground into the second season, and then to reap the seed by hand, over an extended period till all plants had borne seed. There were two disadvantages to this method. Firstly, due to the lack of the cold factor the most undesireable plants tended to be the first to bolt, and selecting seed from these very quickly produced a strain of chicory very prone to bolting. Consequently these had a very high fibre content and presented other disadvantagous characteristics such as low sugar content, low specific density, etc. Secondly, the lack of frost in the area provided ideal conditions for the various leaf-sucking insects such as aphids, Jassids, leaf-hoppers, mites, etc. which transmitted the two virus diseases to which chicory is prone, namely spotted wilt virus and Tobacco Mosaic virus.

(b) During the late seventies, the Agricultural Research Institute at Dohne developed a local selection from Fredonia plants growing in the production area. After due breeding and screening, a pilot scheme for

the production of seed was begun in the Middelburg (Cape) area. The reason for the selection of this area was that, due to the extremely cold winters of the region (soil temperatures can go as low as minus 12 °C), firstly, the plants are very uniformly vernalised, and secondly, leaf-sucking insects are eliminated, thus overcoming the problem of transmission of virus disease. Vernalisation is a physiological reaction in the plant (under the influence of plant hormones) whereby the apical meristem of the plant ceases the formation of embryo leaves and forms the seeding head. Vernalisation occurs in the plant under the combined influence of temperature and photoperiod, and if the correct hormone could be applied to the plant, vernalisation could be achieved without the influence of the cold and photoperiod factors - thus enabling seed production to be undertaken anywhere regardless of geo-physical conditions.

Local seed produced in the Middelburg area has been planted and reaped successfully in the production area, and yields and quality have been satisfactory. This has only been done under experimental conditions as it would appear that labour for hand reaping of seed is a limiting factor. To date only sample quantities have been forthcoming and no local seed has, as yet, been made freely available to growers for production purposes.

## 2.6 CHICORY CULTIVARS (For roasting purposes)

Five main strains of chicory have been developed at various centres in Europe.

1. **PONT DE PIERRE** (Originally bred by the French)

(a) From Royal Sluis in Belgium.

(i) **Rexor.** A selection of Pont de Pierre.

This was superceded by the selection 'Wixor'.

(ii) **Wixor.**

(b) From Florimond deprez - France

(i) **Pevele**

Selections of **Pont de Pierre** are typified as follows:

Leaf: dark green, vigorous.

Root: medium length, rather broad, conical and pointed.

thickest diameter just under the shoulder.

Round shoulder, rather smooth skin.

Has a slight tendency to branching.

Root weight: relatively high.

Dry matter content: moderate.

Dry material: moderate.

Because of shorter, fuller root which is easy to lift, this strain offers the best possibilities for mechanical harvesting.

Rexor is still available to the chicory producers, though it will soon be phased out to be replaced by the superior yielding cultivar, Wixor (a selection of Rexor) which is also currently available.

Cultivars of Pont de Pierre are found to mature rapidly under South African conditions - maturing normally within 28 weeks from germination. These cultivars are best for the light sand commonly encountered in the production area.

Fig. 2.
**Pont de Pierre (Cichorei Rexor) cultivar.**

**2. SMOUTERS** (Also known as Brunswick in South Africa)

(a) From Royal Sluis in Belgium.

(i) **Luxor**

(b) From Florimond desprez in France.

(i) **Flandres**

Selections of Smouters are typified as follows:

**CHICORY LUXOR (TYPE SMOUTERS) i.e. BRUNSWICK**

Leaf: dark green, vigorous.

Root: medium length, broad, conical shouldered, Smooth skin.
Very small percentage of branched roots.

Root weight: relatively high.

Dry matter content: moderate.

Dry material: high.

A smooth skin and a less branched root has been attained by intensive breeding. The medium length of the root makes it less liable to breakage during the lifting process.

Luxor and Flandres are the two Smouters varieties available to producers and takes slightly longer to mature than cultivars of the Pont de Pierre strain, namely 32 weeks.

Smouters varieties give the best results on heavy soils with a high colloidal fraction, i.e. soils such as the heavy red Hutton type soils so prevelant in the area, turf soils, heavy silts and clay soils, etc. Smouters varieties would appear to be the most drought/heat resistant of all the varieties.

Fig. 3.
**Smouters (Cichorei Luxor) cultivar.**

**3. FREDONIA.**

The strain available to growers originates from Austria and is known as Fredonia. A selection exists in Belgium, known as Donor, though this is not available in South Africa.

Fredonia is typified as follows:

Leaf: light green, vigorous.

Root: long, broad, conical and pointed, broad, flat shoulder.

Skin less smooth because of bearded roots.

Rather high percentage of branched roots.

Root weight: moderate.

Dry matter content: very high.

Dry material: moderate.

Interesting strain because of its high dry matter content.

Smoothness of the skin, branching and root weight can be still further improved by selective plant breeding.

Fig. 4.
**Fredonia (Cichorei Donor) cultivar.**

Fredonia is the slowest maturing cultivar, taking up to 36 weeks to achieve its optimum mass. Under South African conditions, it may be rather inclined to bolt if low winter temperatures are encountered. It would appear to have the highest inulin content, and the best dry matter content.

**4. FLAKKEE** (Known in South Africa as Flakkese)

This variety was found to have inferior yielding qualities under local conditions, and its importation was curtailed.

**5. NOVIPA**

Similarly, this variety was found to be badly adapted to local conditions, and it is not available to growers.

## 3. GERMINATION OF CICHORIUM INTYBUS L.

A seed contains an embryonic plant supplied with stored food and is surrounded by a protected seed coat. Once the seed is distributed, if conditions are favourable, the seed will germinate. The germination process comprises a complex series of biochemical and physiological changes which involves the initiation of growth and the mobilization of reserve foods within the seed, to be utilized by the embryo for growth.

Germination has three basic requirements. Firstly, the seed must be viable - the embryo must be alive and capable of germination. Secondly, the seed must be subject to favourable environmental conditions, the essential factors being available water, a satisfactory temperature and an adequate supply of oxygen. Thirdly, seeds may have an innate dormancy or a condition which prevents germination even when the environment is favourable, which must be overcome. Germination takes place in the following stages: imbibition, enzymatic and respiratory activity, digestion, translocation, assimilation and growth.

The initial growth of the seedling follows two patterns. In epigeal germination, as found in **Cichorium intybus L.**, the hypocotyl elongates and raises the cotyledons above the ground (fig. 5). In hypogeal germination, the lengthening of the hypocotyl does not raise the cotyledons above the ground and only the epicotyl emerges.

No known research has been done on germination of chicory in South Africa, and the object of this study was to determine whether, and to what extent, germination is influenced by environmental factors such as temperature, light, water uptake, depth of planting and seed characteristics such as colour and

seed density.

Fig. 5.
**Epigeal germination of chicory seed -
note elongating hypocotyl and presence of root hairs.**

The rate of seeding is 1 kg/ha, with approximately ±600 000 seed per kilogram. The aim is to retain a population density of approximately 150 - 180 000 plants per hectare. Thus, with a germination percentage of 80, only approximately ± 40% of the seeds planted develop into mature plants. This great loss can be ascribed to several factors: planter waste, inaccuracy in seeding, soil condition, incorrect planting depths, insects, diseases and to the fact that certain percentage of the seed is not viable.

## 3.1 THE EFFECT OF TEMPERATURE ON GERMINATION

### 3.1.1 Introduction

The temperature requirements for germination of seeds are generally considered in relation to three cardinal points: minimum, maximum and optimum (Edwards, 1932). The determination of these actual temperatures for any one species is somewhat difficult because temperature affects both the germination percentage and the germination rate (Kotowski, 1926). Minimum temperatures are those below which germination will not occur. The maximum temperatures are the highest at which germination will occur. Optimum temperatures are those most favourable for germination. This should be the range where the highest percentage of seedlings will be produced.

It has long been recognised that different kinds of seed respond differently to germination temperatures. The work of Crocker (1941) indicated that these responses are not only associated with the behaviour of the cells of the embryo, but are further complicated by the seed coat restrictions.

The aim of this study was to determine the optimum germination temperature for the three cultivars of **Cichorium intybus L.**: Pevele, Luxor and Wixor. A further study was to determine whether or not germination is greatly influenced by fluctuating temperatures.

### 3.1.2 Materials and methods

All germination tests were carried out on moistened Whatman no. 1 filter paper (dia. 7 cm), in Petri dishes (dia. 9 cm). One hundred seeds per replicate and four replicates per treatment were used. The seeds were given 16 hours of light and 8 hours of darkness. Readings were taken every 8 hours. The control

for all experiments was placed under normal laboratory conditions and the temperatures were recorded with every germination reading taken. The Wilcoxon two-sample test (Table 1) was used to determine the significance of differences in germination obtained using different temperatures - 20 °C and 35 °C. Germination percentages were tested after 184 hours. The seeds of the three cultivars, Luxor, Pevele and Wixor, were subjected to three constant temperatures: 20 °C, 25 °C and 35 °C. The temperatures of the control fluctuated between 20 and 26 °C during the experiment, giving an average of 23,3 °C.

### 3.1.3 Results

In all three cultivars the best results with constant temperatures were found at 20 °C and 25 °C (fig. 6, 7 and 8). The three cultivars showed the same general pattern during the germination process, except for Luxor, where the germination percentages at 35 °C were much higher than that of Pevele and Wixor. In all three cultivars germination started later, at 20° and 25 °C than at 35 °C. However, a smaller percentage of seed remained ungerminated at 20 and 25 °C. At 35 °C, the rate of germination fell markedly after 48 hours, especially with Wixor and Pevele, showing that at this temperature its maximum for germination could have been reached. The control, fluctuating between 20 and 26 °C, gave the best results overall for Luxor and Pevele.

**TABLE. 1: WILCOXON TWO-SAMPLE TEST - showing the significance effects of various temperatures on the germination of 3 cultivars of chicory**

| Test | | $U_S$ | Probability | |
|---|---|---|---|---|
| Luxor | 20 - 35 °C | 5,5 | > 0,1 | significant ≤ 0,05 |
| Wixor | 20 - 35 °C | 0 | 0,025 | not significant > 0,05 |
| Pevele | 20 - 35 °C | 0 | 0,025 | |

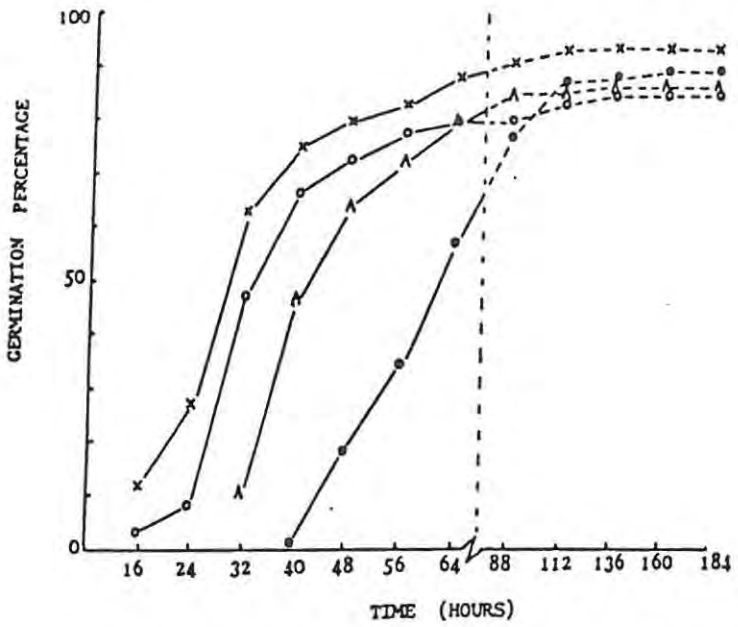



Fig. 6: The effect of temperature on the germination of Cichorium Intybus. L. cv. Luxor seeds.
(Key as for Fig. 8.)

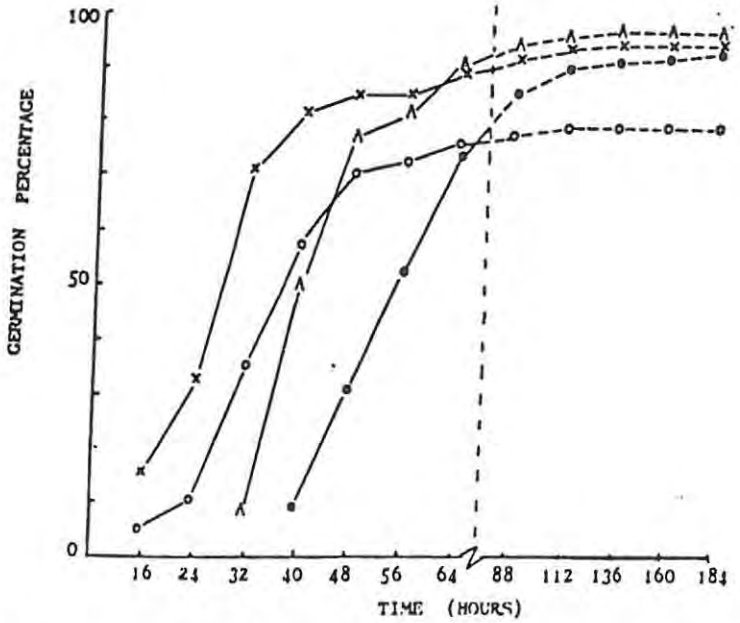
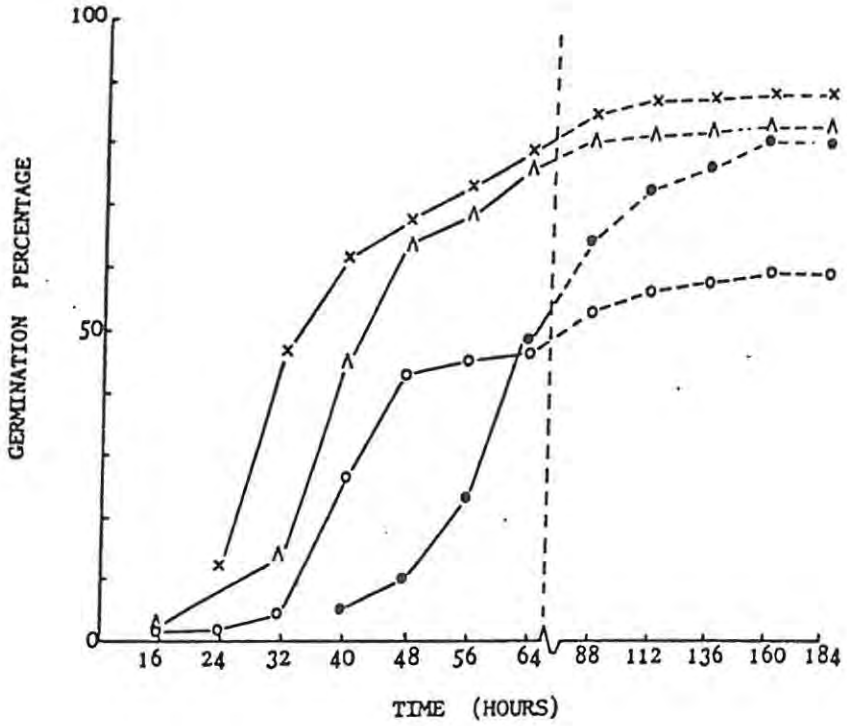
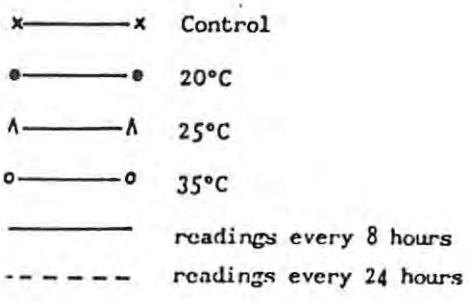



Fig. 7: The effect of temperature on the germination of Cichorium Intybus. L. cv. Wixor seeds.
(Key as for Fig. 8.)

Fig. 8. The effect of temperature on the germination of Cichorium Intybus. L. cv. Pevele seeds.



### 3.1.4 Discussion and Conclusions

Luxor showed little difference in its germination percentages at the three constant temperatures of 20 °C (88%), 25 °C (85%) and 35 °C (84%), while Pevele (58%) and Wixor (78%) showed a definite decrease in germination at a constant temperature of 35 °C. At a constant temperature of 20 °C and 25 °C, all three cultivars gave germination percentages of well above 80%. Valette (1978) said that the highest rate and best uniformity of germination in chicory generally occurred between 20 °C and 25 °C. A good performance at low temperature was associated with good field emergence, growth and crop quality (Valette, 1981). In laboratory studies on the germination of four cultivars of chicory in the temperature range 8 - 35 °C, most cultivars had the best germination at 20 °C (Valette, 1981). Wagenwort, Boot and Bierhuizen (1981) found the best germination at 600 - 2 000 degree hours.

It must be kept in mind that in practice, the seeds will be subject to fluctuatiing temperatures. Although, according to Figs. 6, 7 and 8, chicory does not have an absolute requirement for fluctuating temperatures, the control group, where temperatures fluctuated between 20 °C and 26 °C, gave germination percentages in the region of 90%. Germination is often much better if the seeds are subjected to daily alternating temperatures rather than a constant temperature as might be given in a germinator (Toole et al, 1955). Luxor and Pevele showed better results with fluctuating temperatures. Although Wixor showed better results at a constant temperature of 25 °C (96%), its control (94%) was higher than that of Luxor and Pevele.

Lang (1965) has recorded a large number of accounts of responses to fluctuating temperatures. He commented that 'It is quite possible that further investigation would show the phenomenon to be even more widespread, if

not ubiquitous.' Other parameters of the physical environment may grossly modify temperature responses. Thus Evenari (1965), in a categorization of interactions between fluctuating temperature and light, has distinguished between species in which a fluctuating temperature promotes germination in light or in darkness, those displaying a response only in darkness and those in which promotion occurs only in light. Up until now, chicory has shown no response to light or darkness in relation to fluctuating temperatures.

Although to a lesser extent, differences were found in the three cultivars tested in their response to fluctuating temperatures, the degree of dependence on fluctuating temperature may even vary within a species. For example, strains of cultivated **Apium graveolens L.** (Morinaga, 1926; Thompson, 1974) display considerable differences in their relative responses to constant and fluctuating temperatures. Alternatively, the dependence on fluctuating temperatures may vary from year to year in successive harvests of the same population (e.g. **Silene dioica** Thompson, 1973) or within a single batch of seed during successive phases of post-harvest after ripening (e.g. **Bidens tripartitus**, Rollin, 1956). Townley (1955) found little response to alternating temperatures with certain species of **Rumex L.** Toole, et al (1955) have suggested that changes in temperature act biochemically, perhaps through mechanisms involving enzyme thermodynamics, to alter the concentrations of reactants on which germination depends. Very few attempts have been made to identify the mechanisms controlling responses to fluctuating temperatures.

It can be concluded from the results obtained from this experiment, that temperatures between 20 and 25 °C, whether constant or fluctuating, will be favourable for the germination of chicory seed, and a percentage germination

of between 80% and 90% should be obtained, depending on the cultivar sown and on the inherent germinative capacity of the seed. Wixor gave the best germination, followed by Luxor and Pevele. Germinating Luxor seed can withstand higher temperatures than Wixor and Pevele.

## 3.2 THE EFFECT OF PERICARP COLOUR ON GERMINATION

### 3.2.1 Introduction

The seed coverings may consist of the seed coats, the remains of the nucellus and endosperm, and sometimes parts of the fruit. The seed coats, or testa, usually one or two (rarely three) in number (chicory = 2 + 1 fruiting body), are derived from the integuments of the ovule. During development, the seed coats become modified and at maturity, they present a characteristic appearance. In some cases, the outer seed coat becomes coloured (chicory). The seed coverings may also play an important role in dormancy of some seeds.

Williams and Harper (1965), found that seeds of **Chenopodium album**, with different colours, differ in speed of water uptake. The black seeds require a cold exposure or a supply of nitrates before they will break dormancy. Frankton and Bassett (1968) found that the small black seeds of **Atriplex heterosperma** are produced early in the season, followed by large brown seeds later. The genus **Halogeton** produces brown seeds during long days, but when the plants are transferred to short days, black seeds are produced.

Baar (1912) found that two seed types of **Chenopodium album** differed in their microscopic anatomy in that the testa of the black seeds were about 60$\mu$ thick, and the testa of the brown seeds were about 16$\mu$ thick.

The seeds of **Cichorium intybus L.** vary in size and colour. The purpose of this study is to determine whether or not there is a difference in the germination characteristics of the white, grey (brownish) and black seeds.

### 3.2.2 Materials and Methods

Samples were taken from each of the three cultivars: Luxor, Pevele and Wixor. The seeds of each cultivar were then divided into three colour groups: white, grey to brownish with dark spots, and black. Four replicates with a hundred seeds per replicate were used. The seeds were germinated on moistened Whatman no. 1 filter paper (dia. 7 cm) in petri dishes (dia. 9 cm). Germination took place under normal laboratory conditions with a temperature range between 20°C and 26°C. The seeds were given 16 hours of light and 8 hours of darkness, and readings were taken every 8 hours, for a period of 64 hours, after which a reading was taken every 24 hours.

### 3.2.3 Results

Significant results were obtained for Luxor and Wixor seeds as can be seen from the Wilcoxon two-sample test done in Table 2.

**TABLE 2: WILCOXON TWO-SAMPLE TEST - showing the significance of seed colour in the germination of 3 cultivars of chicory.**

| | TEST | $U_S$ | PROBABILITY |
|---|---|---|---|
| Luxor: | black and white | 1 | 0,05 |
| Luxor: | grey and white | 0 | 0,025 |
| Wixor: | black and white | 0 | 0,025 |
| | grey and white | 3 | 0,10 |
| Pevele: | black and white | 2 | > 0,05 |
| | grey and white | 6 | > 0,10 |

significant $\leq 0,05$
not significant $> 0,05$

### 3.2.4 Discussion and Conclusions

The germination of the three groups showed the same germination pattern for all three cultivars (Figs. 9, 10 and 11). In all three cultivars the darker

Fig.9. The effect of seed colour on the germination of Cichorium intybus. L. cv. Luxor seeds.
(Key as for Fig.11)

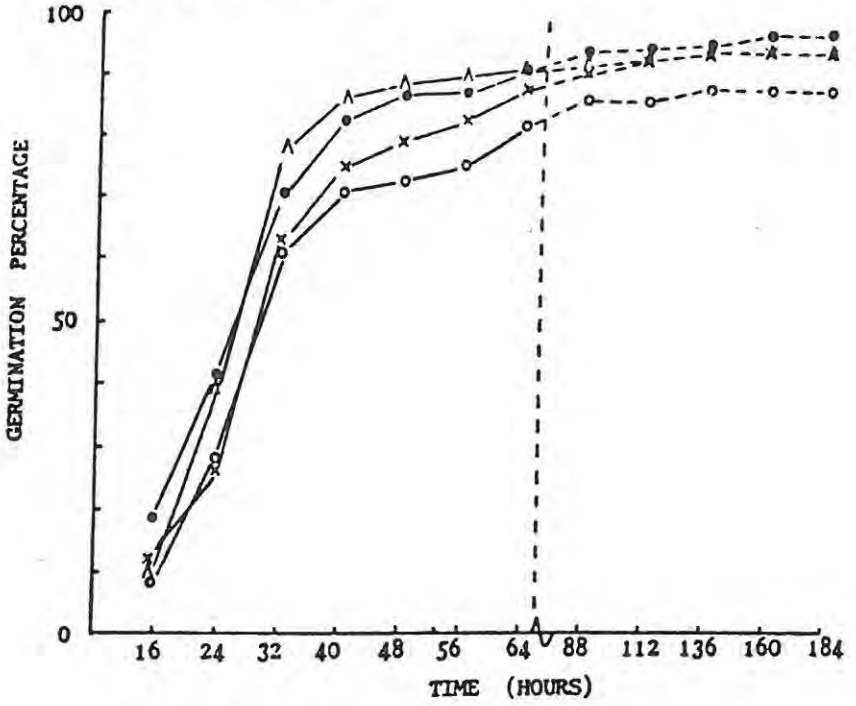



Fig. 10. The effect of seed colour on the germination of Cichorium intybus.L. cv. Wixor seeds.
(Key as for Fig. 11)

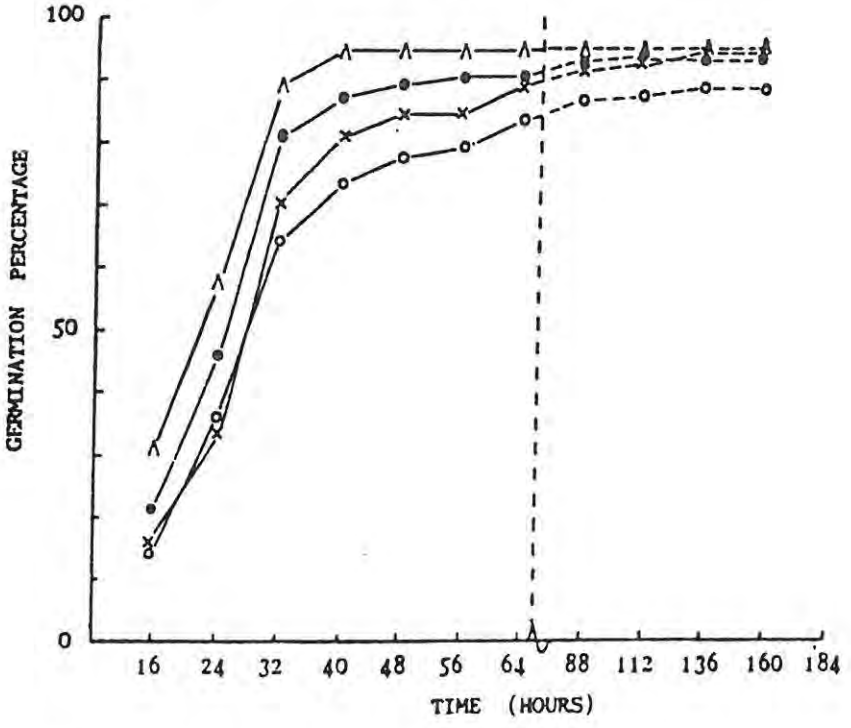
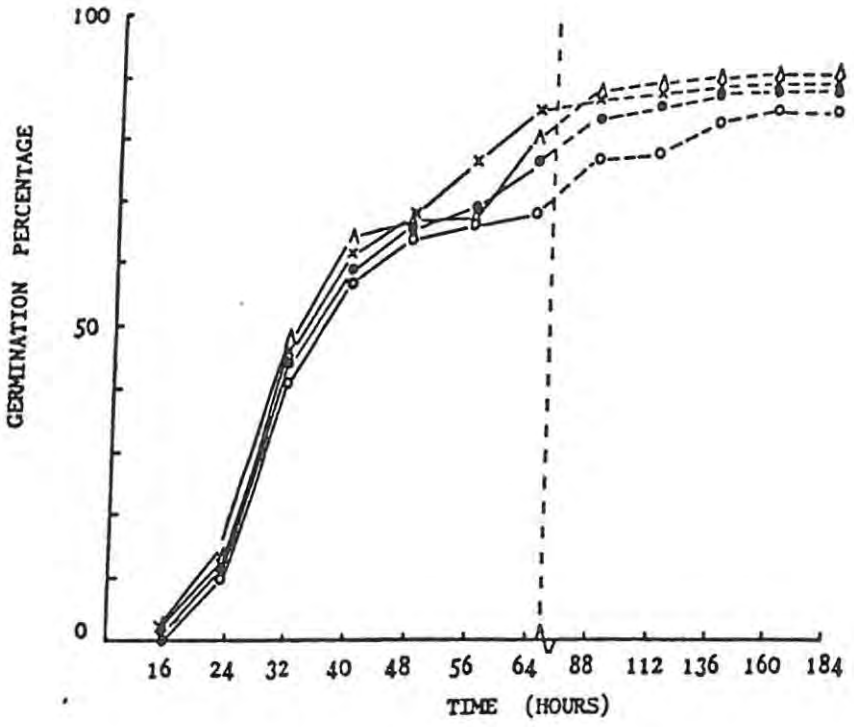


Fig. 11: The effect of seed colour on the germination of Cichorium intybus. L. cv. Pevele seeds.




x——x Control

●——● Grey

Λ——Λ Black

o——o White

——— reading every 8 hours

- - - - - reading every 24 hours.

seeds showed the highest percentages, and although the white seeds had the lowest germination percentage, they were still well above 80%. According to the Wilcoxon two-sample test (Table 2), significant results were obtained from: Luxor - between black and white seeds, and grey and white seeds - and Wixor - only between black and white seeds. The results of the control group in which the three colours were mixed, represented a good average of the three individually tested groups.

The sample taken from each cultivar consisted of approximately 65% grey, 21% white and 14% black seeds, bringing the total of the darker seeds to approximately 80% of the total. Although these percentages can vary, the majority of seeds borne by **Cichorium intybus L.** are grey/brown. The white and black seeds are, on average, usually larger in size, but are present in smaller numbers.

The reasons for the variation in seed colour may be somewhat complex but could possibly be related to seasonal variations, temperature/humidity conditions at ripening, position of the flower on the capitulum and possibly even inherent characteristics of individual plants.

## 3.3 THE EFFECT OF WATER UPTAKE AND SEED DENSITY ON GERMINATION

### 3.3.1 Introduction

Apart from certain cases where a cold, heat or infra-red factor are a prerequisite, imbibition of water by the seed is the first step in the germination process. The two most important factors which affect water uptake by seeds are:

(i) the nature of the seed and its covering, and

(ii) the amount of the available water in the surrounding medium.

Seeds have great absorbing power due to their colloidal nature (Schull, 1916). Different kinds of seeds vary greatly in the amount and rate of water absorbed, either in storage, or during germination (Stiles, 1948). The rate of water uptake is also influenced by temperature, a higher temperature favouring an increased rate (Shull, 1920). The moisture supplied to the germinating seed may affect both the germination percentage and the germination rate (Doneen and MacGillivray, 1943; Hunter and Erickson, 1952). Studies done on vegetable plants to determine their moisture requirements for germination, showed that **Cichorium endive** and beet will germinate in soils from intermediate moisture content to above field capacity (Harrington and Minges, 1954).

In this experiment, the object is to determine whether the germination of seeds of **Cichorium intybus L.** is influenced by water uptake by the seeds, and seed density.

### 3.3.2 Materials and Methods

Seed of three cultivars - Luxor, Pevele and Wixor- were placed in beakers with water, and were left for half an hour. The seeds were seperated into two categories: those which sank to the bottom, and those which remained on the

surface of the water. A hundred seeds per replicate, and four replicates per treatment, were used to determine the germination percentage in each category. The seeds were germinated on moistened Whatman no. 1 filter paper in petri dishes, under normal laboratory conditions with a temperature range of 20 °C - 26 °C.

### 3.3.3 Results

Although the best results were obtained with the more dense seeds which sank to the bottom of the beakers (figs. 12, 13 and 14), the differences were found not to be significant when subjected to the Wilcoxon two-sample test.

**TABLE 3. WILCOXON TWO-SAMPLE TEST - showing the significance of seed density in the germination of 3 cultivars of chicory.**

| | TEST | $U_S$ | PROBABILITY |
|---|---|---|---|
| Pevele: | surface and bottom | 7,5 | $>0,1$ |
| Wixor: | surface and bottom | 5,5 | $>0,1$ |
| Luxor: | surface and bottom | 2,0 | $>0,05$ |

significant $\leq 0,05$
not significant $>0,05$

### 3.3.4 Discussion and Conclusions

The Luxor and Wixor seeds which sank to the bottom gave a slightly higher germination percentage (though not significantly higher - 2%) than the control which were not placed in water at all (figs. 13 and 14). The differences in the germination percentages between the two groups and the control was between two and four percent. Both of these two groups in all three cultivars gave germination percentages of well above 80%, and the same germination pattern was obtained throughout the experiment. Water uptake in relation to seed

Fig. 12. The effect of water uptake or seed density on the germination of Cichorium intybus. L. cv. Pevele seeds. (Key as for Fig. 14.)

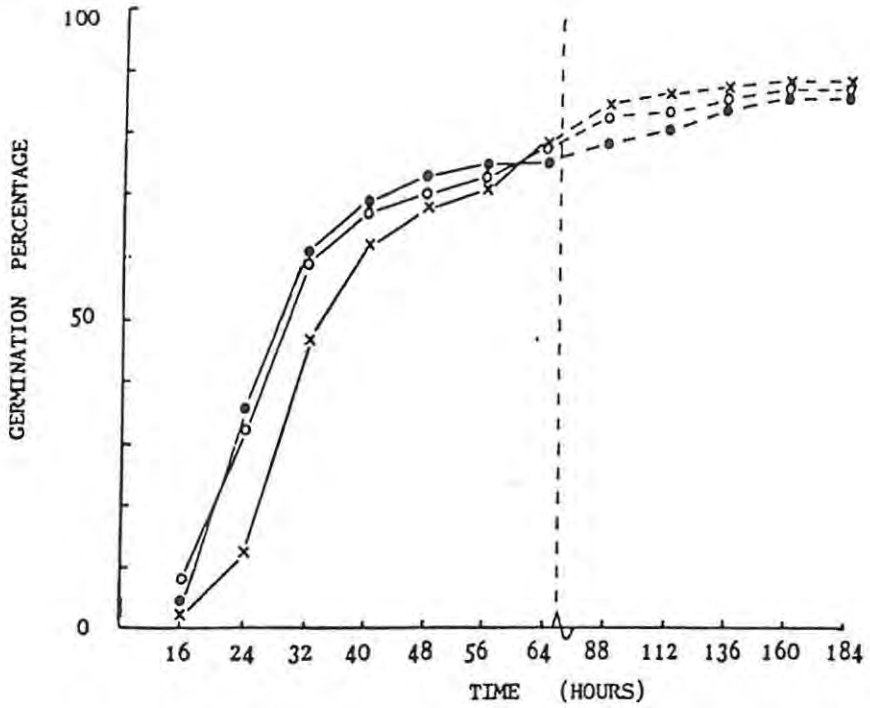



Fig. 13. The effect of water uptake or seed density on the germination of Cichorium intybus. L. cv. Wixor seeds. (Key as for Fig. 14.)

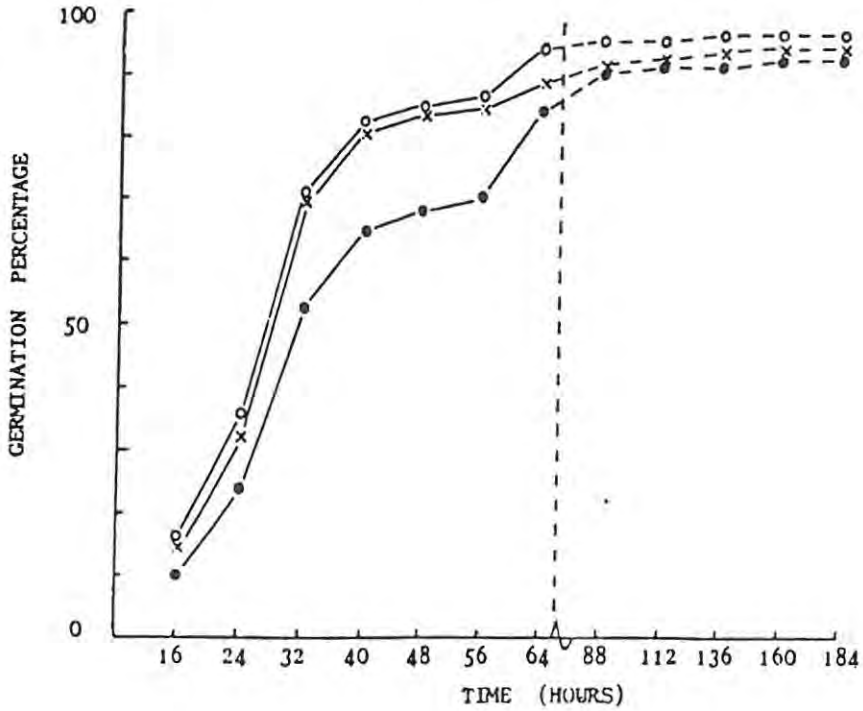
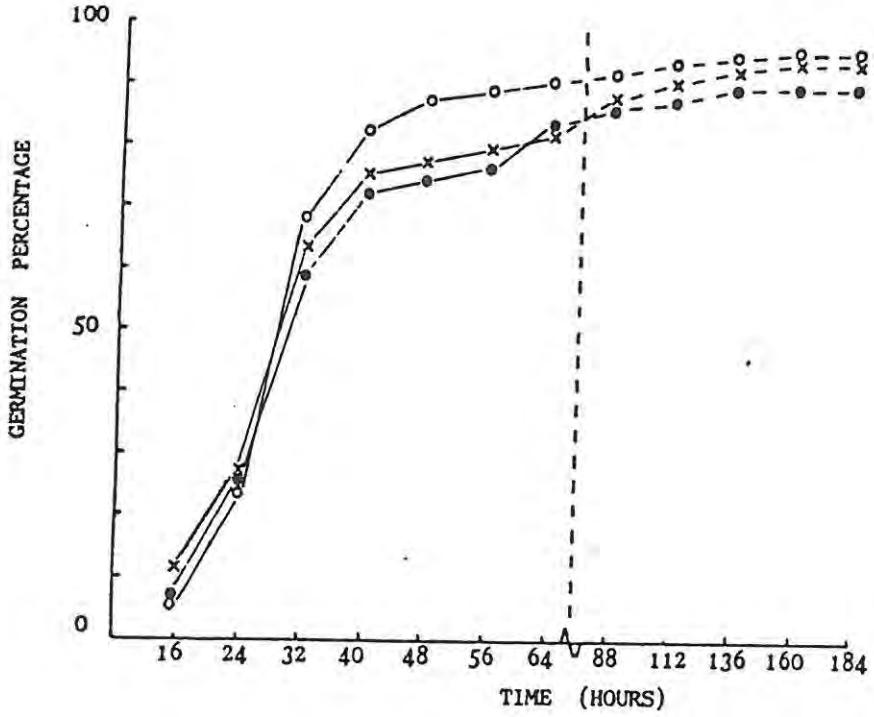
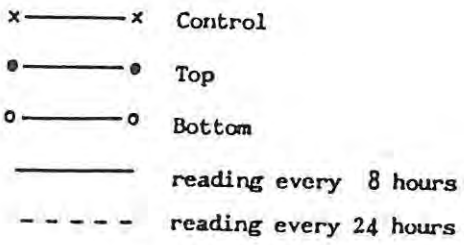


Fig. 14. The effect of water uptake or seed density on the germination of Cichorium intybus. L. cv. Luxor seeds.



density, as done in this experiment has no marked influence on the germination of **Cichorium intybus L.**

**Note:**

During this experiment, it was found that some seeds tended to have a minute air-bubble adhering to the pappus end of the achene, and this caused otherwise dense seeds, which should have sunk, to float, thus influencing the results obtained.

## 3.4 THE EFFECT OF VARIED SEED SIZE AND DEPTH OF PLANTING ON SEEDLING EMERGENCE

### 3.4.1 Introduction

In this experiment, seeds of **Cichorium intybus L.** were seperated into two seed sizes to determine whether seed size and depth of planting plays an important role in seedling emergence.

The influence of size of seed upon the subsequent growth and ultimate yield has been examined at various times for a number of species of economic importance (Kidd and West, 1919; Kitowski, 1926; West, 1930). The general conclusion to be drawn from these reviews and from more recently published data, is that, in an annual plant, early growth is dependent on, or even proportional to, the size of the seed. However, only a few studies have been made on the influence of seed size on the growth of pasture legumes. Fruwirth (1917; quoted by Kidd and West, 1919) working with lucerne and sainfoin, found that better crops were obtained by the use of larger seed, though with perennial plants, the initial advantage fails to persist. Findley (1919) and Schmidt (1921) using clover, demonstrated that in the early stages of growth, production was markedly dependent on seed size.

### 3.4.2 Materials and Method

Two seed sizes were used in this experiment: large seeds (length $\geq$ 2 mm, diameter $\geq$1 mm), and small seeds (length <2 mm, diameter <1 mm). They were planted in trays. The seeds were placed on the surface of the soil, and in rows at depths of ½ cm, 1 cm, 1½ cm, 2 cm, 3 cm, and 4 cm, with 3 replicates and 50 seeds per replicate. The seeds were germinated under normal laboratory conditions at a temperature range of between 20 and 30 °C. Three

cultivars - Luxor, Pevele and Wixor - were used, and each cultivar was divided into two seed sizes and each size was planted at various depths as mentioned.

### 3.4.3 Results

Poor results were obtained with seedling emergence when seeds were planted below a depth of 3 cm (Figs. 15 - 21).

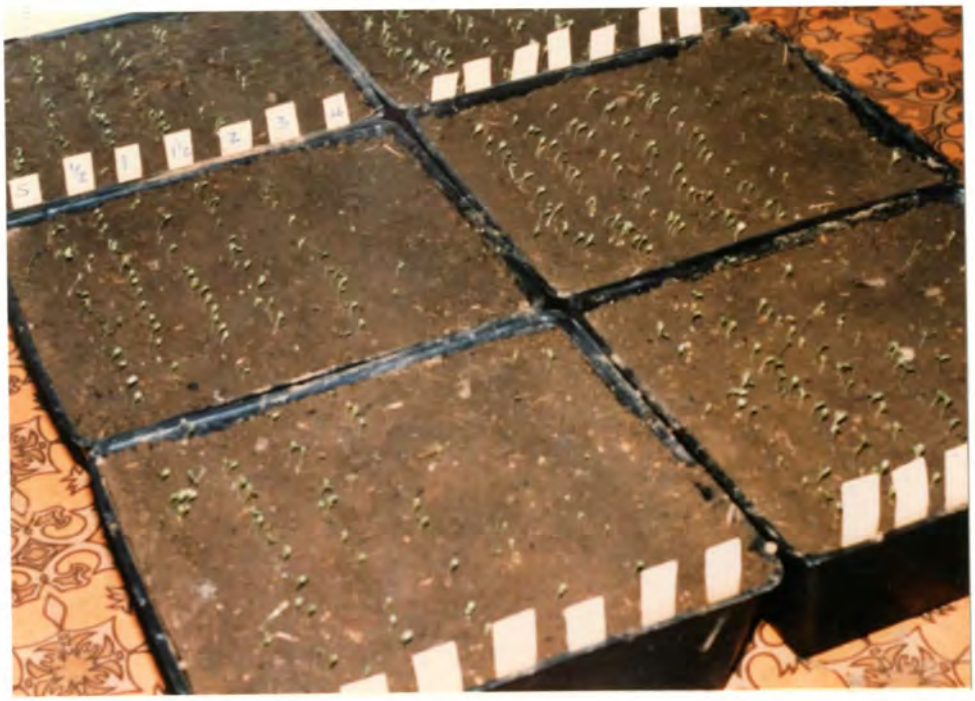


Fig. 15.
**Seed emerging from various depths, with small seeds on the left and large seeds in the trays on the right.**

Fig. 16. The effect of different depths of planting on the emergence of small seeds of Cichorium intybus L. cv. Luxor seeds.

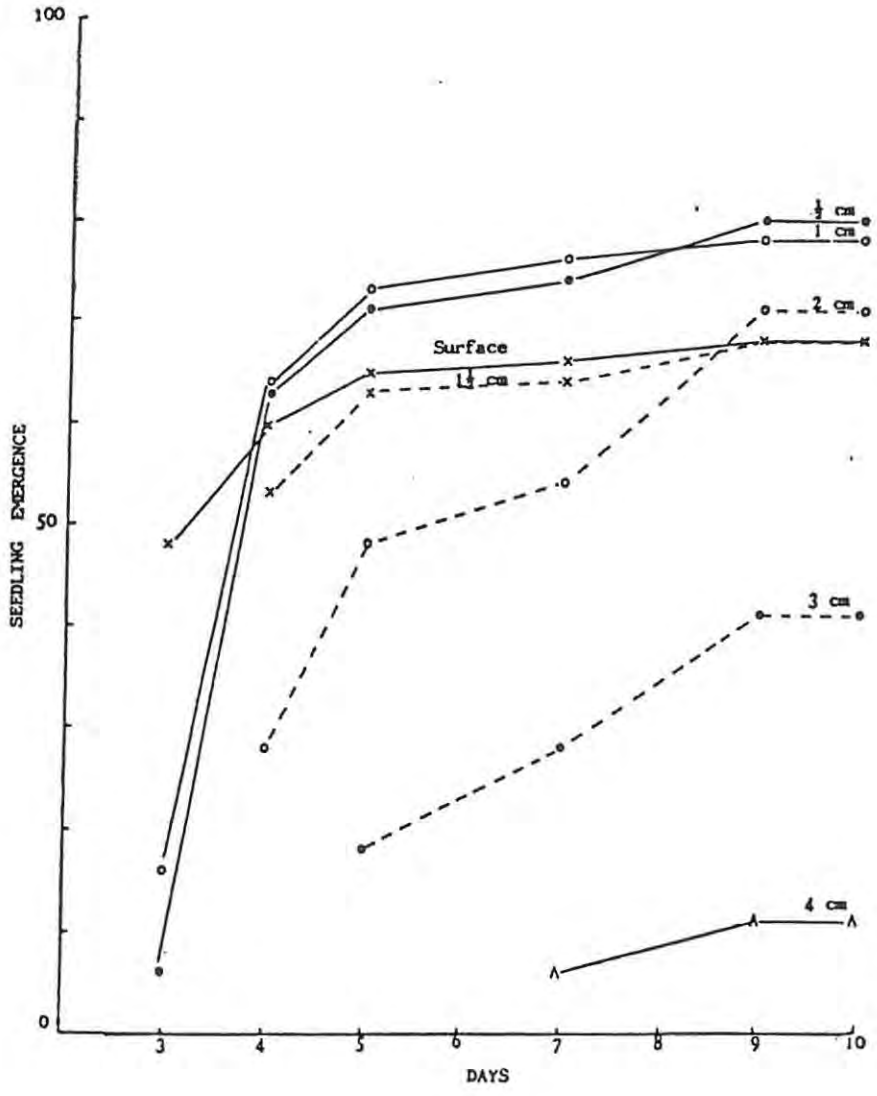


Fig. 17. The effect of different depths of planting on the emergence of large seeds of Cichorium intybus L. cv. Luxor seeds.

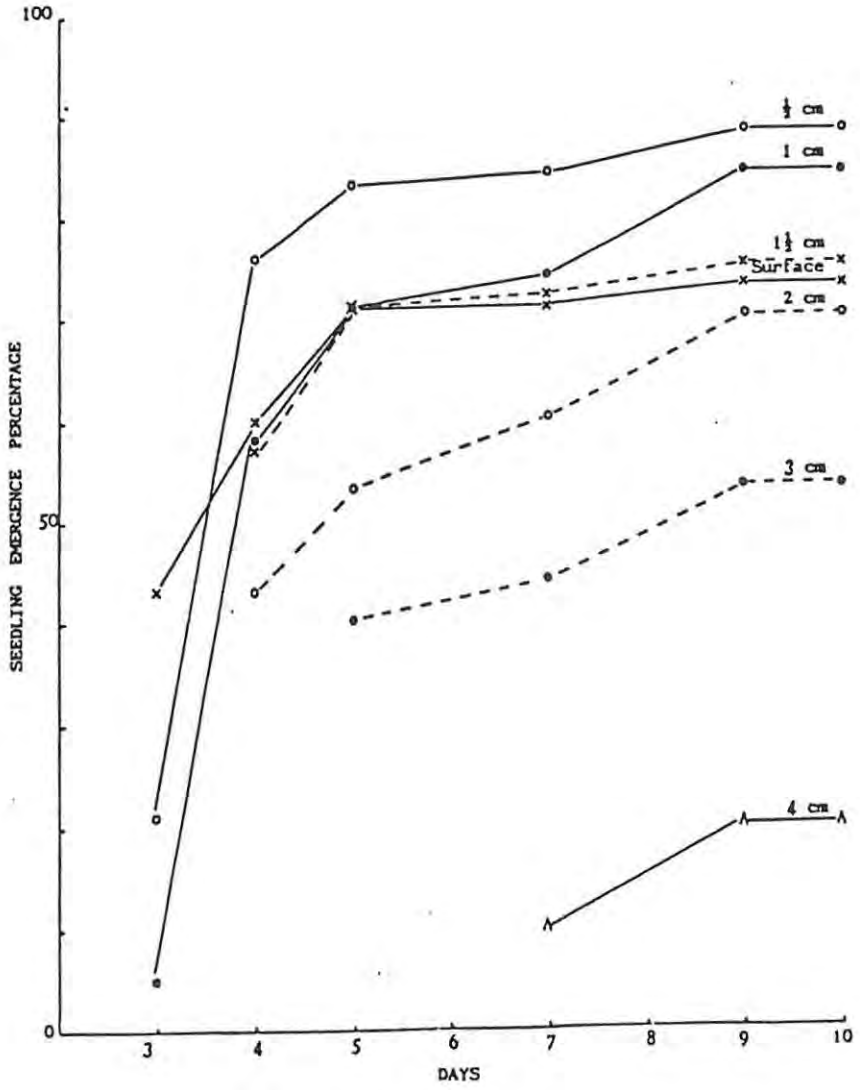


Fig. 18. The effect of different depths of planting on the emergence of small seeds of Cichorium intybus L. cv. Pevele seeds.

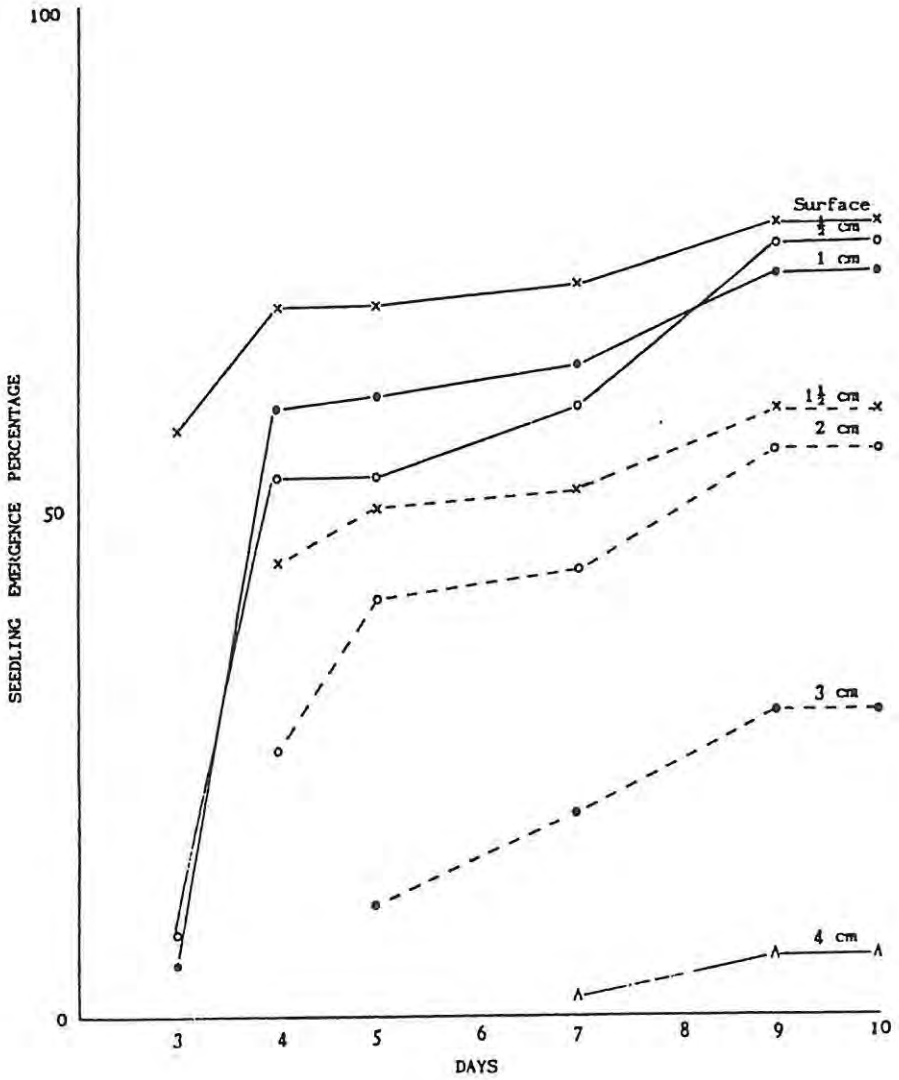


Fig. 19. The effect of different depths of planting on the emergence of large seeds of Cichorium intybus L. cv. Pevele seeds.

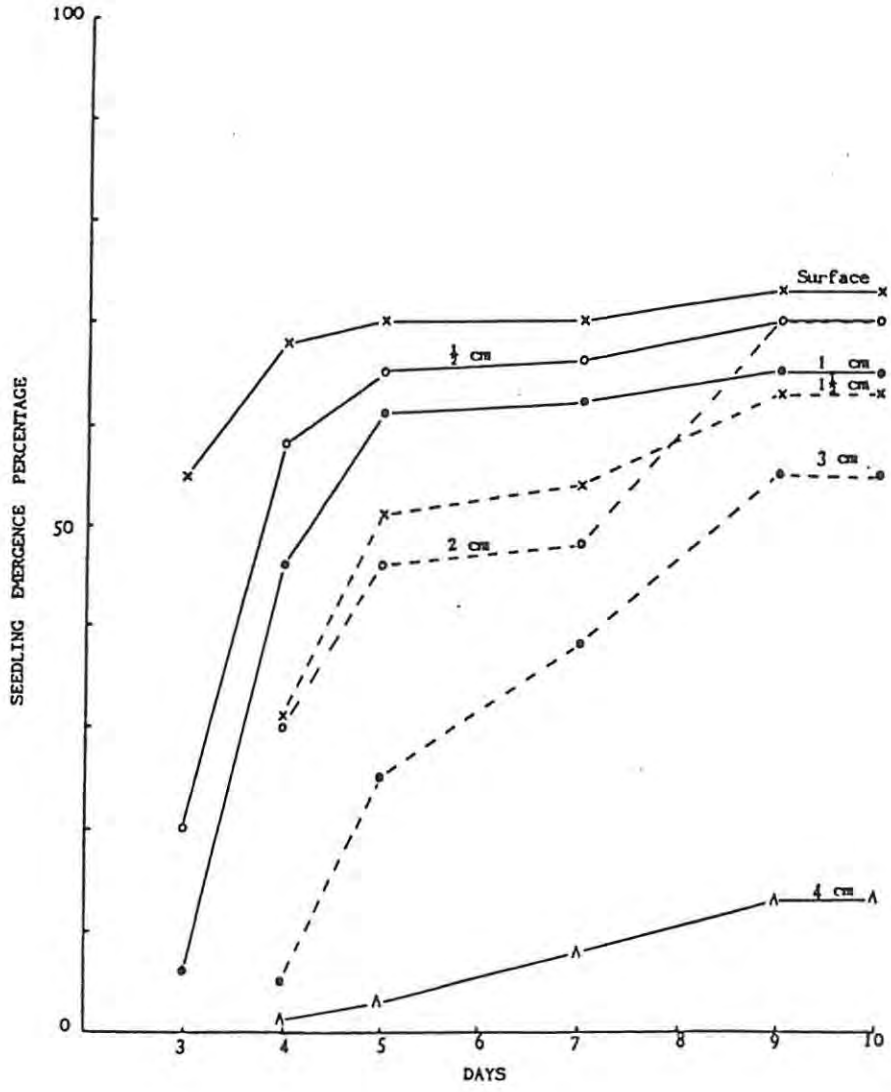


Fig. 20. The effect of different depths of planting on the emergence of small seeds of Cichorium intybus L. cv. Wixor seeds.

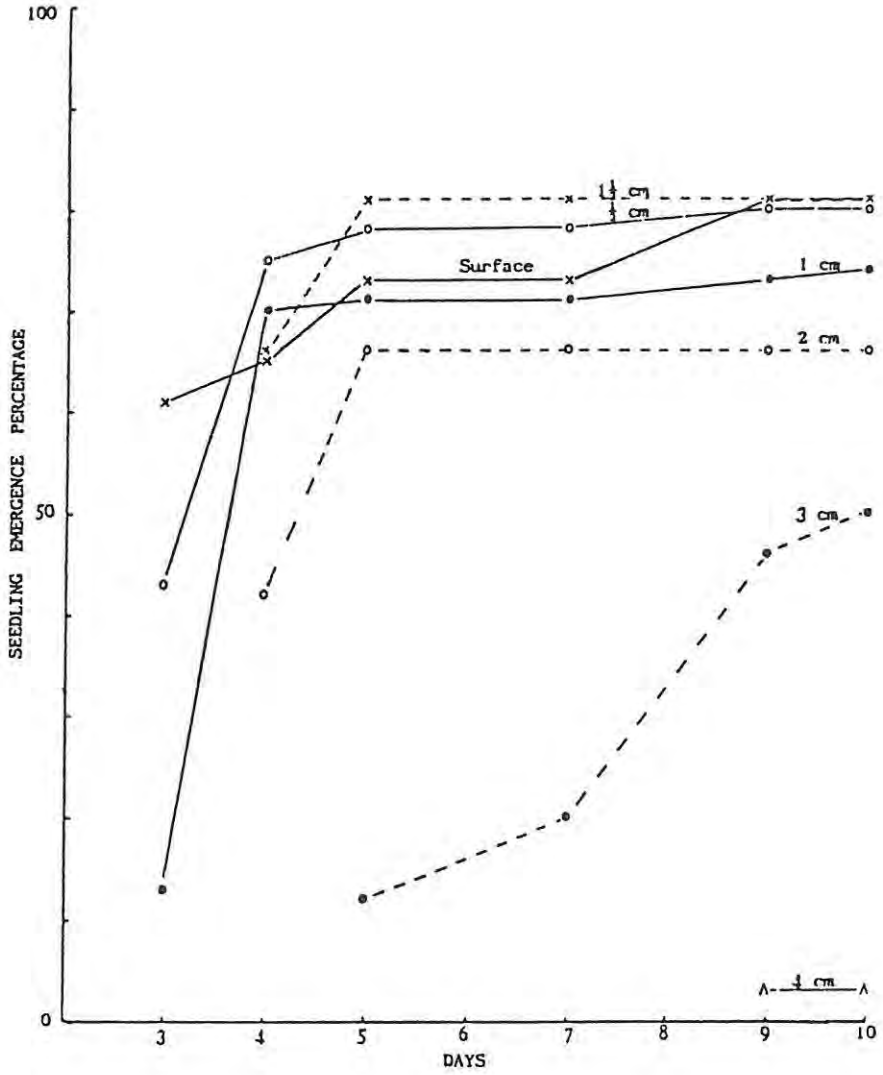


Fig. 21. The effect of different depths of planting on the emergence of large seeds of Cichorium intybus. L. cv. Wixor seeds.

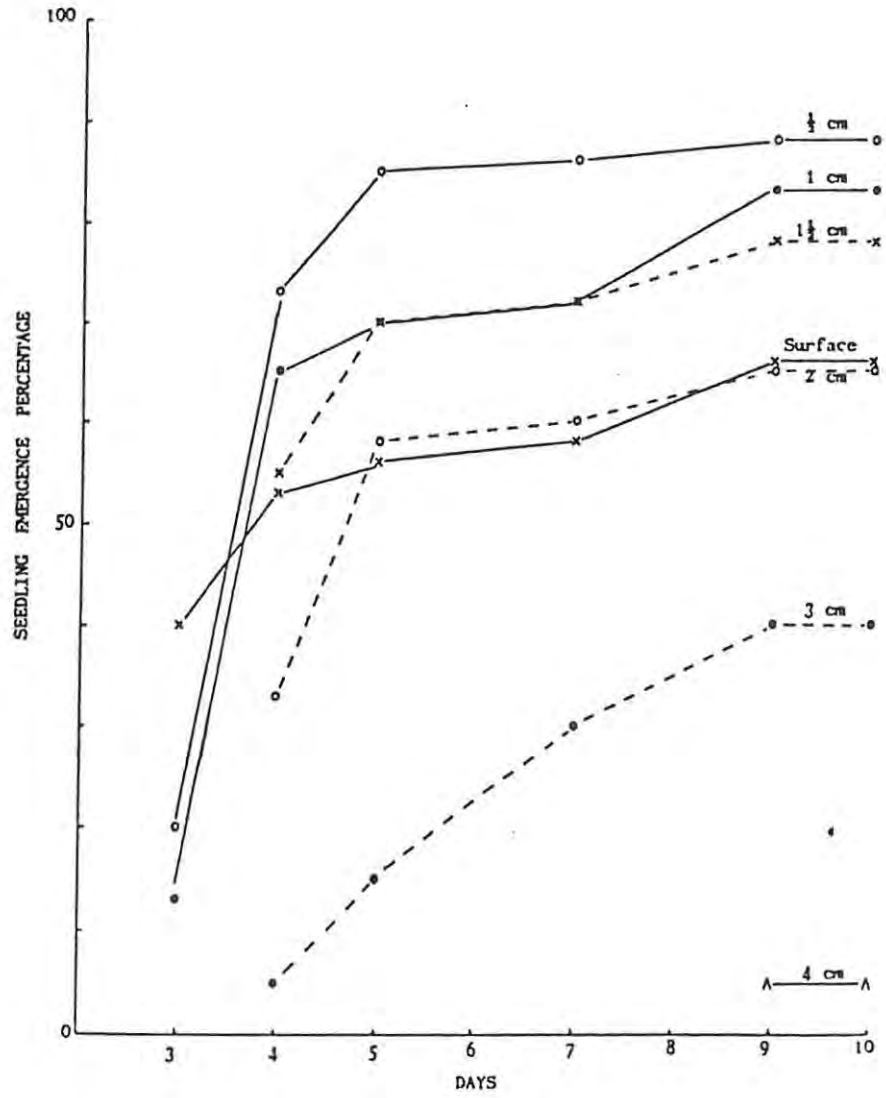


**TABLE 4: WILCOXON TWO-SAMPLE TEST - showing the significant effects of various depths of planting on seedling emergence of 3 cultivars of chicory.**

| TEST | | | $U_s$ | PROBABILITY |
|---|---|---|---|---|
| Wixor | (small) | ½ cm + 1 cm | 2,5 | > 0,1 |
| | | 1 cm 2 cm | 3 | > 0,1 |
| | | 2 cm 3 cm | 0 | 0,05 |
| Wixor | (large) | 1 cm 1½ cm | 3 | > 0,1 |
| | | 1½ cm 2 cm | 2,5 | > 0,1 |
| | | 2 cm 3 cm | 0 | 0,05 |
| Pevele | (small) | ½ cm 1 cm | 4,5 | > 0,1 |
| | | 1½ cm 2 cm | 3,5 | > 0,1 |
| | | 2 cm 3 cm | 0 | 0,05 |
| Pevele | (large) | 1 cm 2 cm | 3,5 | > 0,1 |
| | | 1 cm ½ cm | 4 | > 0,1 |
| | | 2 cm 3 cm | 0 | 0,05 |
| Luxor | (small) | ½ cm 1 cm | 4 | > 0,1 |
| | | 1½ cm 2 cm | 3 | > 0,1 |
| | | 2 cm 3 cm | 0 | 0,05 |
| Luxor | (large) | ½ cm 1 cm | 3 | > 0,1 |
| | | 1½ cm 2 cm | 2,5 | > 0,1 |
| | | 2 cm 3 cm | 0 | 0,05 |

significant $\leq 0,05$
not significant $> 0,05$

Except for Pevele, at depths of a ½ cm and 1 cm, the large seeds gave better seedling emergence than the small seeds. Seed planted below 3 cm depth gave poor results and only the large seeds of Luxor and Pevele gave a percentage of seedling emergence at 3 cm of just above 50%. According to the Wilcoxon two-sample test (Table 4), significant results were obtained only between the 2 cm and 3 cm depths for all of the cultivars.

### 3.4.4 Discussion and Conclusions

Germination of seed on the surface was high in Pevele, but gave poor results with Luxor and Wixor. In practice, surface germination will be of no significance because of environmental factors influencing the stand of the seedlings. The seed can be blown by wind, washed away by water or even be picked up by insects and birds which results in a poor stand.

Seedling emergence at 3 cm depth and below was poor in relation to the other depths. Black (1955) said that depth of sowing had no effect on subsequent growth of pasture legumes, provided that the critical depth had been determined by the seed size. Fruwirth (1917) said that plants from greater depths of sowing will be at a disadvantage as compared with those from shallower sowings, since emergence will be progressively delayed as depth of sowing increases

From results obtained from this experiment, it can be concluded that seedling emergence will give the best results when the seeds are planted not deeper than approximately 2 cm. The population density per hectare in practice, can be influenced by many factors such as inaccuracy of seeding, insects, diseases, clods, soil crust, etc. The depth of planting seeds of **Cichorium intybus L.** can also be influenced by soil type, texture and structure. If you have, for instance, a soil with a tendency to crust, you must plant at a shallower depth.

**Practical implications of Planting depth**

**A. Hot conditions:** (high insulation intensity/low humidity)

**Deeper sowing** (i.e 10 mm plus) In order to protect the seed from germinating in the event of light rains and or extended dews, seeds are deeply planted. Soil is normally very dry at these times and light rains fail to produce satisfactory soil moisture levels. Thus, seeds germinate, penetrate a layer of bone-dry soil and die. Another criterion is that in summer the soil surface can dry within hours of a rainfall, leaving the seed to emerge into dry conditions, unable to utilize moisture at 1,5 cm or more down in the soil.

**2. Cool and cold conditions** (low insulation intensity/high humidity)

In winter and especially away from the coastal zones, chicory seed seems to germinate very slowly and they germinate best right on the soil surface and down to a depth of 2 mm. This is , it would seem, due to the influence of temperature. However, germination of chicory would appear to be influenced by the effect of near red light, and at low temperatures, this may play a significant role. Experiments with infra-red light would be justified.

**3. Soil Conditions**

The clay fraction/organic matter content of the soil vastly influences the soil's tendency to crust. This is a great problem in the field, and where it is likely to occur, shallower planting is advocated to enable emergence before the soil has time to form a crust after the rain.

**4. Type of rain**

The grower has no influence over rainfall. Light drizzles have proven to be the best. If heavy rain occurs, seeds frequently wash out of the soil.

Thus, it can be concluded that depending on soil type, environmental factors such as temperature and availability of moisture, planting can vary between a ½ cm and a maximum of 2 cm depth.

## 3.5 THE EFFECT OF LIGHT ON GERMINATION

### 3.5.1 Introduction

Sensitivity of seeds to light has been shown by many investigators to be modified by temperature, certain chemicals (inhibitors and promotors) and various other factors. These factors interact with each other and with the physiological condition of the seed as influenced by genotype, age conditions during maturation, harvest and storage. The interactions have been the subject of several reviews (e.g. Borthwick, 1965; Evenari, 1956, 1961; Toole et al, 1956; Toole, 1961; Toole, 1963).

A higher percentage germination is usually obtained when seeds are exposed to light, but Hughes (1938) recorded a higher percentage germination of **Rumex crispus** in darkness.

Among cultivated plants there is very little evidence for light as a factor influencing germination. The seeds of most cultivated plants usually germinate equally well in the dark and in the light. (Mayer and Poljakoff-Mayber, 1982).

Seeds may be divided into those which germinate only in the dark, those which germinate only in continuous light, those which germinate after being given a brief illumination and those which are indifferent to the presence or absence of light during germination.

### 3.5.2 Materials and Methods

Three culitvars were used: Luxor, Pevele and Wixor. For each cultivar there were two treatments, one in the dark and one in the light. Each treatment consisted of four replicates with one hundred seeds in each replicate. The

seeds were germinated under normal laboratory conditions. They were placed on moistened Whatman no. 1 filter paper in petri dishes. The filter paper was kept moist throughout the experiment. Temperatures fluctuated between 19° and 26°C.

### 3.5.3 Results

After four days, no significant results were obtained from the Wilcoxon two-sample test (Table 5), with the exception of the Luxor experiment.

**TABLE 5: WILCOXON TWO-SAMPLE TEST - showing the effect of various lengths of exposure to light and dark on the germination of the seeds of 3 cultivars of chicory.**

| TEST | $U_s$ | PROBABILITY |
|---|---|---|
| Luxor : after 4 days - light and dark | 0 | 0,025 |
| : after 6 days - light and dark | 6 | |
| Wixor : after 4 days - light and dark | 4 | |
| : after 6 days - light and dark | 7,5 | |
| Pevele : after 4 days - light and dark | 4 | |
| : after 6 days - light and dark | 6 | |

significant $\leq 0,05$
not significant $> 0,05$

According to figures 22 and 23, germination occurred faster in the dark than it did in the light, over the the first 3 days. The germination percentages in the light increased after 3 days to give an even end-result for seeds germinating in the light and dark. The germination percentages for light and dark followed more or less the same pattern during the experiment for all three cultivars. Luxor and Wixor gave the highest germination percentages, followed by Pevele.

Fig. 22. The effect of light on the germination of Cichorium intybus L. seeds. The three cultivars used were Luxor, Wixor and Pevele.

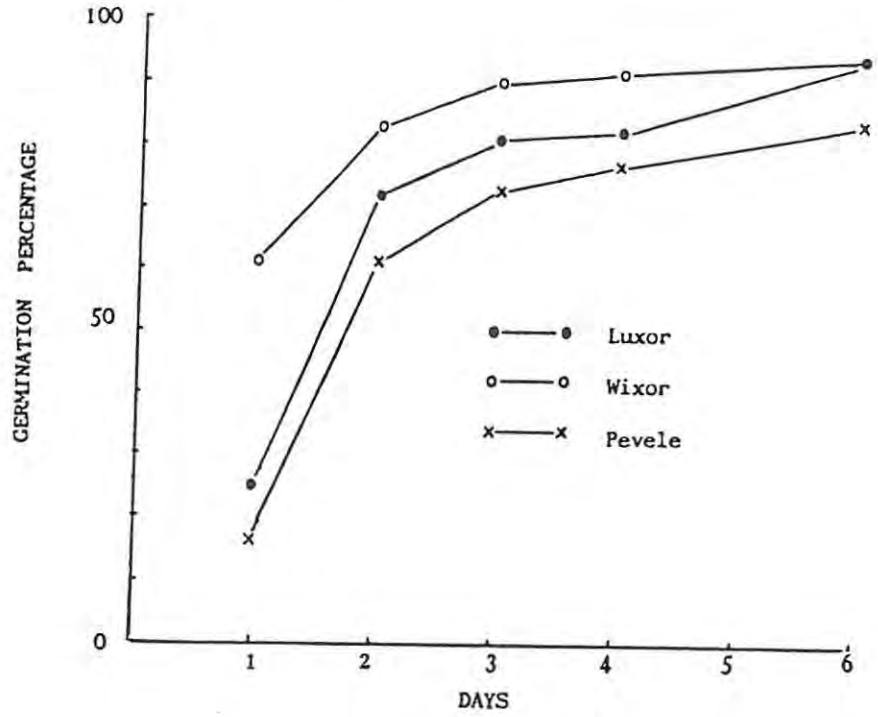
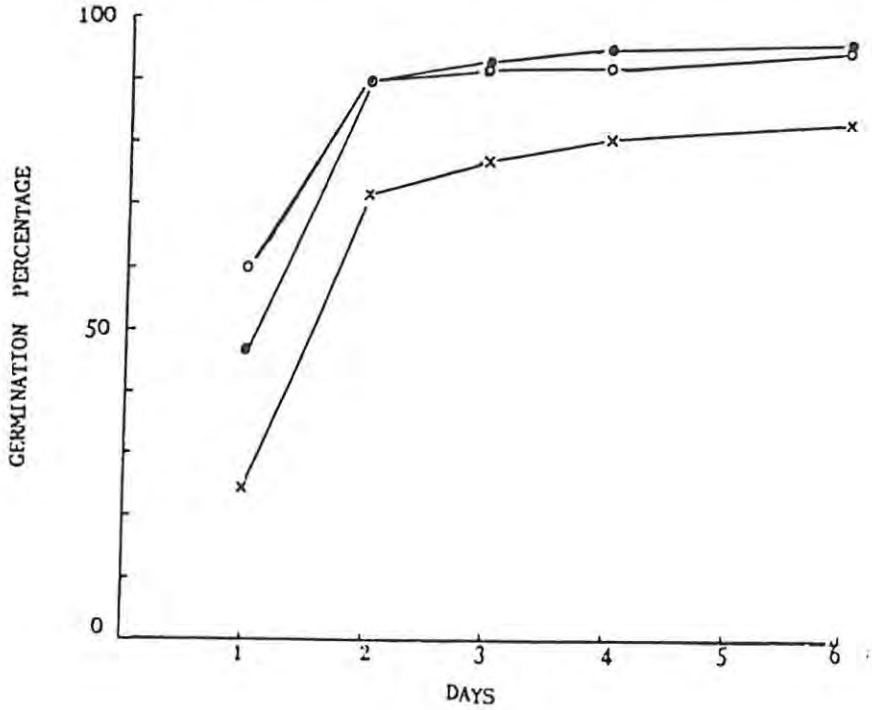



Fig. 23. The effect of darkness on the germination of Cichorium intybus L. seeds. The three cultivars used were Luxor, Wixor and Pevele.
(Key as for Fig. 22.)



A similar experiment was conducted in complete darkness for six days. At the end of this period counts of germinating seeds were made to determine whether or not germination might be influenced by a period of complete darkness. In the first experiment the germinating seeds were exposed to low light intensities when they were being counted. The following results were obtained:

TABLE 5A: FINAL PERCENTAGE GERMINATION OF SEEDS EXPOSED TO LOW LIGHT INTENSITY (Experiment 1) AND COMPLETE DARKENSS (Experiment 2)

| | 1st experiment % germination | 2nd experiment % germination |
|---|---|---|
| Luxor - dark | 95 | 84,6 |
| Wixor - dark | 94 | 84 |
| Pevele - dark | 83 | 76,6 |

The lower germination percentages attained during the second experiment can be ascribed to the much lower temperature range (14 - 22°C) at which the experiment was carried out compared with the initial experiment.

### 3.5.4 DISCUSSION AND CONCLUSIONS

The lower germination percentage in Pevele can be ascribed to a possible lower viability of the seeds, or a tendency to a light-dark environment. The control done on Pevele in experiment 1 gave more or less the same end result as in this experiment, thus leaving the last mentioned factor unfounded. Although the germination percentage of Pevele at 84% was lower than that of Luxor and Wixor at 94%, it was still well above the 70% requirement for germination.

From the results of the second experiment (Table 5A) germination was apparently not influenced by the short exposure to light during the daily counting of the seeds.

It could be said, from the results obtained from this experiment, that **Chichorium intybus L.** is not dependent on light or darkness for germination. In the early stages of germination, darkness might well have a stimulating influence on some cultivars, but overall over the final period, the same end result may occur. Other factors, such as temperature, might well have an influence.

## 4. FLOWERING AND SEED PRODUCTION OF CICHORIUM INTYBUS L.

The appearance of flowers is perhaps the most impressive event in plant development, and we know that there are at least three important morphological or environmental conditions that control or influence the initiation of flowers. For a plant to be able to flower, it is necessary to attain a certain stage of morphological development, such as the differentiation of a certain number of nodes, before flower initiation can occur. A second phenomenon is the influence of the relative lengths of the days and nights on flower initiation, a response referred to as **photoperiodism.** Thirdly, some plants require the inductive influence of a period of low temperature which makes possible the initiation of flowers at a subsequent time, a process referred to as **vernalisation.**

Plants may be grouped into three photoperiodic classes with respect to their requirements for flower formation.

i) **Long-day** plants flower only after they have been exposed to daylight periods of more than a certain length about 14 hours in every twenty-four. If given shorter days, they remain vegetative.

ii) **Short-day** plants flower only if provided with less than a certain length of daylight, about ten hours in every twenty four.

iii) The flowering of **intermediate** plants is independent of day length.

Chicory is a long-day plant, with a critical daylength of about of 13 hours (Margara, 1977).

In general, plants that require two years to complete their lifecycle (biennials) have this two year cycle because of a cold requirement. The term **vernalisation** is used when flower initiation is caused by a pre-cold

treatment. During the first year **Cichorium intybus L.** shows an extensive development of leaves and a large root.

In nature, in its wild state, on the steppes of eastern Europe, the chicory plant, **Cichorium intybus L.**, germinates from seed in the spring and developes a fleshy tap-root system during that summer and autumn to serve as a carbohydrate reserve to carry the plants through the severe winter conditions and to provide the plant with most of the energy required to take the plant through the seeding phase and to the culmination of the cycle, the eventual production of viable seed (Luckman, 1984).

The critical point in this cycle, which is of paramount importance, is when the plant switches from developing the storage organ, the tap root, to the development of the seeding stalk, (this stage is called **floral differentiation**) flowering and eventual seed formation. At this point vernalisation occurs, and is in actual fact a hormonal change within the plant, controlled by the apical meristem. The physiological processes involved in these morphogenetic changes are not well understood, but a number of interesting facts have been discovered. Using histochemical techniques, a number of investigators, particularly Gifford and his students, have found that upon the arrival of the flowering stimulus, there is marked increase in ribonucleic-acid (RNA) and proteins. Electronmicrographs have revealed an increase in the number of ribosomes, and the complexity of the endoplasmic reticulum of the apical meristem cells (Gifford and Stewart, 1965). Bonner and Zeevart, 1962, found that 5-flourouracil (an inhibitor of RNA synthesis) applied to **Xanthium** buds prevents the flowering of photoperiodically induced plants. Facts such as this suggest that florigen, like other hormones, may

act by altering the kinds of mRNA synthesized, thus changing the enzyme complex of the meristematic cells and the processes leading to morphogenetic changes. However, this remains largely theoretical and does little to explain the shifts in differentiation as the flower parts develop.

The morphogenetic changes that result in the conversion of a vegetative bud primordium into a flower bud begins soon after florigen reaches the primordium from the leaves. The first cytological evidence is increased cell division just below the apical initials. Then flower primordia rather than leaf and lateral bud primordia begin developing. There is generally also an enlargement and change in shape of the apical meristem. Salisbury (1963) has identified a series of eight floral stages that can be used as a semiquantitative measure of the degree of photoperiodic induction.

## 4.1 THE EFFECT OF COLD TREATMENT OF CHICORY ROOTS ON FLOWERING

### 4.1.1 Introduction

The term vernalisation (work done by Murneek and Whyte, 1948, and Purvis, 1936) was coined in 1928, by the Russian agronomist, Lysenko, who worked on this phenomenon, but there had been previous reports of vernalisation by others such as Gassner in Germany in 1918. Vernalisation is the promotion of flowering by low temperature preconditioning at any stage in the life of a plant. Some plants that require vernalisation or have their flowering promoted by it, also have a subsequent photoperiodism requirement.

A number of researchers on cereal crops have found that vernalisation stimulated flowering. Gregory and Purvis (1936), Kostjucenko and Zaburailo (1937), Riddel and Gries (1958) and Schwabe (1963) had all reported on vernalisation.

Aucamp and Mai (1981) found that cold treatment resulted in earlier growth when chicory roots were replanted in July, enhanced the forming of flowering stems, and influenced the amount of inflorescences that formed. They also found that with a high rainfall, the plants grew faster, and longer flowering stalks were formed, which were easily blown over by the wind and broken. The aspect of irrigation during seed-production must be investigated.

The vernalisation changes occurring in chicory have been examined (Rutherford and Weston, 1968), and when the roots are forced, prior cold storage has been shown to be a yield- (Huyskes, 1962) and quality- (Rutherford and Jackson, 1965) determining factor.

The vernalisation changes occurring within chicory root have been examined with respect to the storage carbohydrates (Rutherford and Jackson, 1965), and the related enzymes (Rutherford and Phillips, 1971). It has been found that during cold storage, there is a considerable breakdown of the storage polysaccharide, inulin, to form oligofructosans. Rutherford and Jackson (1965) have demonstrated that most of these changes occur within six to eight weeks, when the roots are stored at 3 °C, and that the breakdown of the storage carbohydrates is necessary for the production of good quality chicons when the roots are subsequently forced.

The object of this study is to determine the effect of cold storage on flowering roots of **Cichorium intybus L.** Furthermore, it was decided to investigate the effect of different cold temperatures, constant and fluctuating, and different time periods on the amount of flowering and seed production.

**4.1.2 Materials and methods**

The experiment was carried out on the Chicory Board's lands. Roots, varying in size (Table 6), were collected from a nearby farm in the Salem district. The roots were approximately 7 months of age. The leaves were cut off at the base of the petiole and the roots were seperated into two root-size groups - roots smaller than 4 cm in diameter at the crown, with an average size of 3,26 cm, and roots bigger, or equal to, 4 cm, with an average diameter of 4,81 cm at the crown.

Each size group consisted of 180 roots which was divided into groups of 15 roots each. These groups were packed in wet sand and then placed in a cool room at 4 °C and 10 °C, respectively, for a constant period of 2, 4 and 6 weeks. The remainder of the groups of the same root-size group were then placed at

| 15/8/83 (6 weeks) | | | | | | 29/8/83 (4 weeks) | | | | | | 12/9/83 (2 weeks) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| small * | | | large * | | | small * | | | large * | | | small * | | | large * | | |
| (<4 cm) | | | (>4 cm) | | | (<4 cm) | | | (>4 cm) | | | (<4 cm) | | | (>4 cm) | | |
| 3,6 | 3,3 | 3,5 | 4,2 | 4,6 | 5,1 | 3,8 | 3,8 | 3,8 | 5,7 | 5,3 | 5,7 | 3,0 | 3,1 | 3,0 | 6,0 | 5,0 | 4,5 |
| 3,1 | 2,6 | 3,6 | 4,5 | 4,7 | 4,4 | 3,8 | 2,7 | 3,9 | 5,2 | 5,5 | 5,3 | 2,7 | 2,4 | 3,0 | 4,7 | 4,9 | 4,9 |
| 2,5 | 3,0 | 3,1 | 6,4 | 4,3 | 4,4 | 3,9 | 3,9 | 3,9 | 6,0 | 5,1 | 5,9 | 2,2 | 2,5 | 3,1 | 5,1 | 4,2 | 5,2 |
| 2,8 | 3,2 | 3,3 | 4,5 | 4,2 | 5,0 | 3,0 | 3,9 | 3,5 | 5,5 | 4,8 | 4,4 | 2,5 | 2,5 | 3,6 | 4,9 | 4,1 | 6,8 |
| 3,3 | 3,4 | 3,6 | 4,6 | 4,5 | 4,6 | 3,3 | 3,7 | 3,7 | 5,4 | 4,8 | 4,3 | 2,3 | 2,5 | 2,5 | 4,6 | 4,I | 5,4 |
| 3,5 | 3,4 | 3,4 | 4,3 | 5,4 | 4,6 | 3,8 | 3,9 | 3,5 | 5,9 | 4,5 | 4,6 | 2,3 | 2,8 | 2,7 | 4,9 | 4,7 | 4,9 |
| 2,9 | 3,0 | 3,5 | 4,7 | 4,8 | 5,6 | 3,6 | 3,9 | 3,9 | 4,7 | 4,3 | 4,7 | 2,2 | 2,7 | 3,1 | 4,1 | 4,7 | 4,1 |
| 2,5 | 2,7 | 3,7 | 4,8 | 5,1 | 4,2 | 3,4 | 3,8 | 3,8 | 4,5 | 4,9 | 4,5 | 2,6 | 3,1 | 3,1 | 4,8 | 5,1 | 4,2 |
| 3,5 | 3,1 | 3,7 | 5,0 | 5,2 | 4,4 | 2,9 | 3,7 | 3,8 | 5,2 | 4,8 | 4,1 | 2,4 | 3,1 | 3,1 | 4,7 | 5,4 | 4,3 |
| 2,8 | 3,3 | 3,1 | 5,4 | 5,0 | 4,7 | 2,5 | 3,7 | 3,9 | 4,5 | 4,4 | 4,6 | 2,6 | 3,0 | 3,2 | 4,8 | 4,4 | 4,3 |
| 3,1 | 3,0 | 3,6 | 5,6 | 4,4 | 4,3 | 3,3 | 2,9 | 3,7 | 4,5 | 5,8 | 4,0 | 3,3 | 2,5 | 3,1 | 4,3 | 4,5 | 4,1 |
| 3,6 | 3,0 | 3,2 | 5,4 | 4,5 | 4,8 | 2,6 | 2,8 | 3,9 | 4,4 | 5,2 | 4,1 | 2,6 | 3,1 | 3,1 | 4,0 | 5,2 | 4,1 |
| 3,6 | 3,4 | 3,5 | 4,7 | 4,8 | 4,0 | 2,8 | 3,0 | 3,8 | 5,0 | 4,8 | 4,0 | 2,8 | 2,3 | 3 1 | 4,9 | 4,2 | 4,0 |
| 3,4 | 3,2 | 244,8 x | 4,6 | 4,3 | 352,1 x | 3,8 | 2,5 | 256,9 x | 4,4 | 4,6 | 369,6 x | 2,5 | 2,6 | 233,1 x | 4,5 | 4,3 | 361,1 x |
| 3,4 | 3,6 | 3,26 o | 4,6 | 4,3 | 4,69 o | 3,8 | 2,6 | 3,42 o | 4,4 | 4,3 | 4,93 o | 2,4 | 3,1 | 3,1 o | 4,6 | 5,2 | 4,81 o |
| 3,8 | 3,6 | | 4,9 | 4,9 | | 3,9 | 2,5 | | 4,5 | 4,8 | | 2,8 | 2,7 | | 4,1 | 4,9 | |
| 3,7 | 3,4 | | 4,1 | 4,2 | | 3,3 | 2,3 | | 4,4 | 4,9 | | 2,3 | 3,2 | | 4,7 | 4,9 | |
| 3,4 | 2,9 | | 4,0 | 4,2 | | 3,0 | 3,2 | | 5,0 | 5,2 | | 3,2 | 3,4 | | 4,3 | 4,9 | |
| 3,3 | 2,5 | | 4,8 | 5,5 | | 3,2 | 3,1 | | 5,4 | 4,3 | | 2,4 | 3,6 | | 4,8 | 4,9 | |
| 3,1 | 3,4 | | 4,8 | 4,4 | | 3,6 | 3,8 | | 5,2 | 4,6 | | 2,7 | 3,4 | | 4,7 | 5,5 | |
| 3,4 | 3,8 | | 4,6 | 4,2 | | 3,5 | 3,0 | | 4,3 | 4,2 | | 3,2 | 3,1 | | 5,4 | 4,4 | |
| 3,6 | 2,8 | | 4,8 | 5,1 | | 3,8 | 3,2 | | 5,6 | 4,6 | | 3,6 | 2,9 | | 6,5 | 5,1 | |
| 3,8 | 2,5 | | 5,6 | 4,8 | | 3,7 | 2,6 | | 4,8 | 4,8 | | 3,1 | 3,1 | | 6,1 | 5,3 | |
| 3,3 | 2,0 | | 4,3 | 4,1 | | 2,6 | 3,2 | | 5,3 | 4,7 | | 3,3 | 2,4 | | 5,5 | 4,8 | |
| 3,6 | 3,9 | | 5,1 | 5,3 | | 3,6 | 3,6 | | 5,5 | 4,6 | | 2,9 | 2,9 | | 4,7 | 4,6 | |
| 3,7 | 3,9 | | 4,1 | 4,1 | | 3,8 | 3,1 | | 4,9 | 4,7 | | 3,1 | 3,1 | | 5,2 | 4,4 | |
| 3,7 | 2,6 | | 4,3 | 5,0 | | 3,9 | 3,5 | | 5,4 | 4,7 | | 2,0 | 2,9 | | 4,7 | 4,3 | |
| 2,7 | 3,4 | | 4,4 | 5,2 | | 3,2 | 3,3 | | 5,7 | 4,8 | | 2,7 | 3,1 | | 4,1 | 4,4 | |
| 3,7 | 3,8 | | 4,7 | 4,5 | | 3,9 | 3,1 | | 5,3 | 5,5 | | 2,8 | 2,3 | | 5,4 | 6,0 | |
| 3,2 | 2,8 | | 4,5 | 5,1 | | 2,7 | 3,8 | | 6,4 | 4,6 | | 2,9 | 2,1 | | 5,5 | 5,2 | |
| 3,4 | 2,5 | | 5,0 | 4,0 | | 3,8 | 3,9 | | 6,9 | 5,4 | | 3,0 | 2,8 | | 5,2 | 4,9 | |

x = Total.
o = Mean.

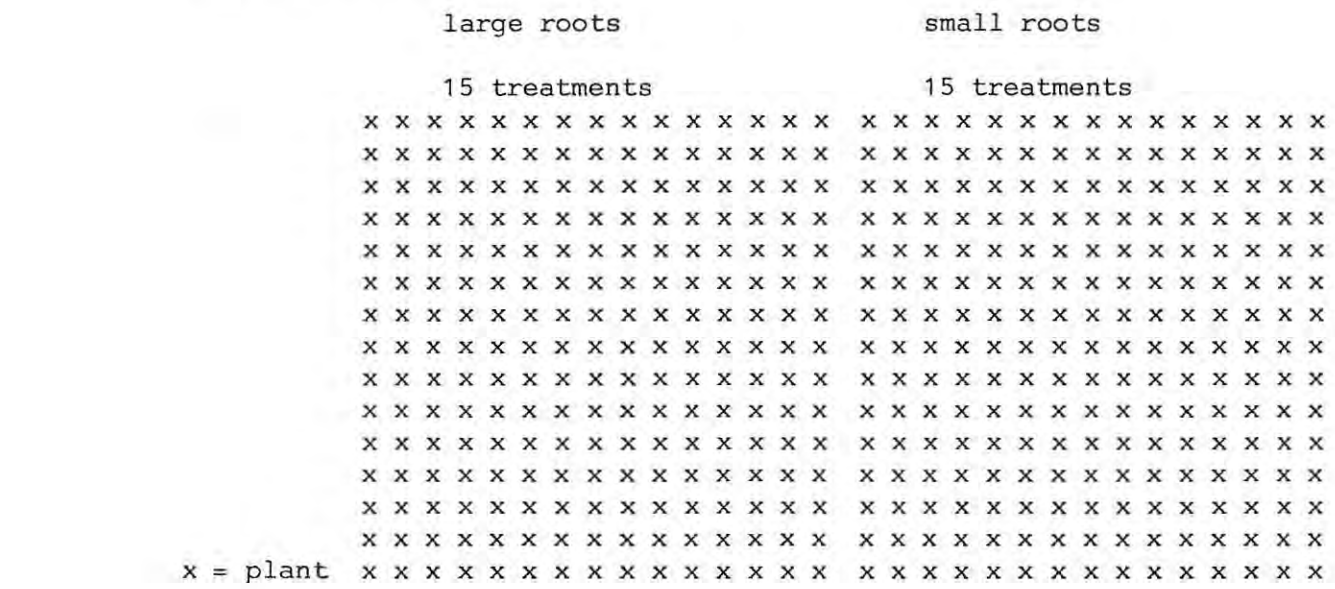
TABLE 6. Showing the diameter of the roots in the small and large groups during the 3 periods of cold treatment.

* Each of these 75 roots were divided into 5 treatments of 15 roots each, as follows: 4 C - constant temperature
4 C - fluctuating temperatures
10 C - constant temperatures
10 C - fluctuating temperatures
Control

4 °C and 10 °C, for 2, 4 and 6 weeks, but the temperature of these roots fluctuated by placing them in the cool-room for 12 hours at night and taking them out during the day, thus, simulating natural conditions. The second size group was treated in the same manner. The control roots (90 in total = 4 groups) were also packed in wet sand, but left outside, under natural conditions. The total number of roots used during this experiment amounted to 450.

After six weeks, all the roots were planted out at the same time (29/9/83) in an experimental block. The roots were planted one metre apart, within a row which consisted of 30 roots in 2 groups - large and small. The rows were spaced one metre apart, to give a total of 15 rows.

**Experimental Block**




Weekly recordings were made of plants which grew, differentiated and flowered. The rainfall (Table 7) was recorded, and temperature and humidity readings were taken from automatic recordings produced on thermohygrographs (figs. 24 and 25) from the time that the roots were placed in the cold rooms.

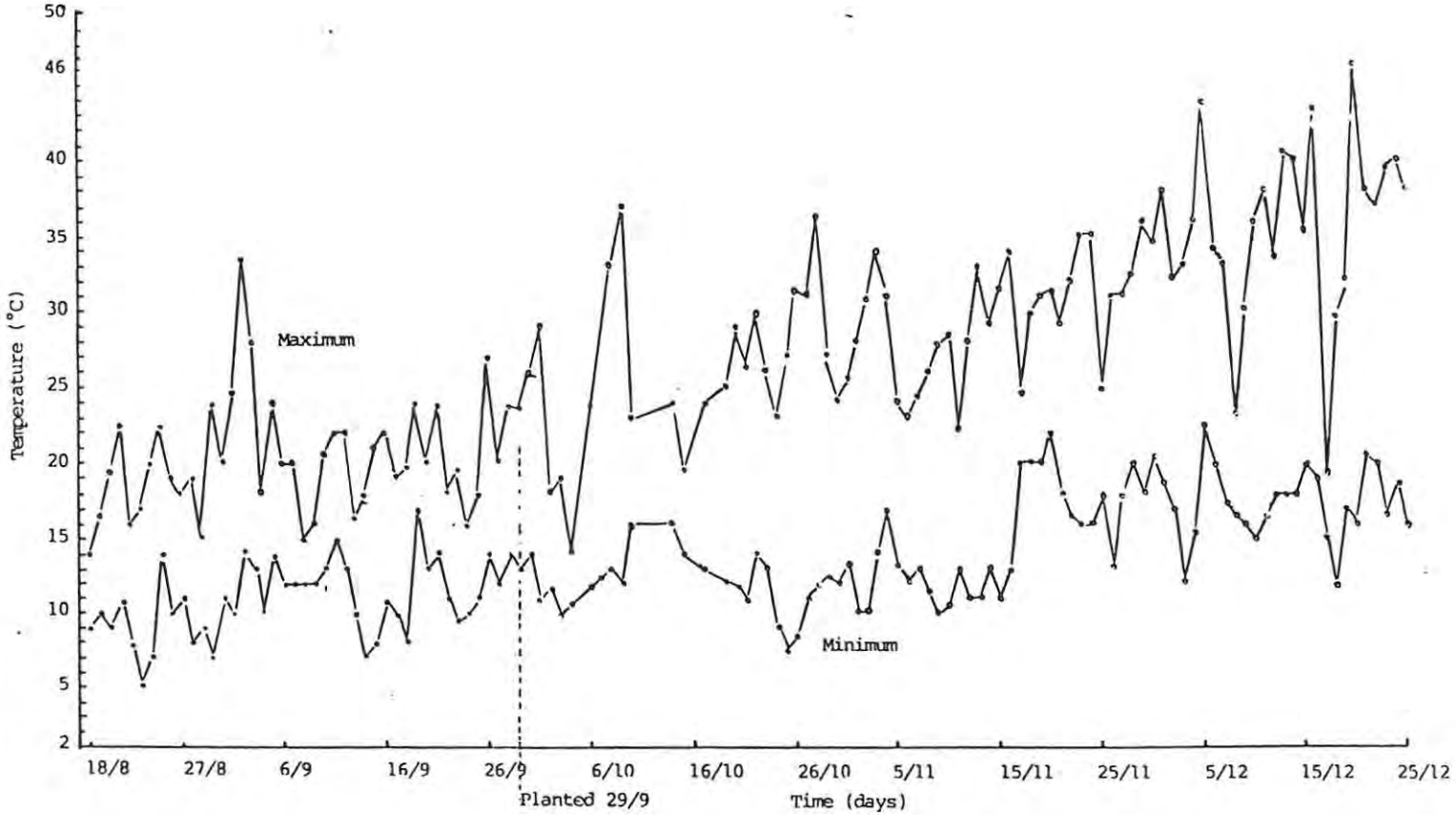
The seeds were all reaped on the same day (26/1/84), and were weighed and tested for viability.

**TABLE 7:** The average rainfall record over a period of 60 years, and a rainfall record taken over the duration of the growing period of the chicory used in the experiment.

**Rainfall**

| Month | | 1983/84 season | 60 year average |
|---|---|---|---|
| Jan. | 1983 | 23,0 mm | 53,0 mm |
| Feb. | | 66,0 | 77,5 |
| March | | 27,5 | 130,0 |
| April | | 28,0 | 72,0 |
| May | | 47,0 | 81,0 |
| June | | 36,0 | 49,0 |
| July | | 246,0 | 41,0 |
| Aug. | | 23,0 | 60,0 |
| Sept. | | 62,5 | 99,0 |
| Oct. | | 72,5 | 81,5 |
| Nov. | | 47,0 | 81,0 |
| Dec. | | 55,0 | 79,0 |
| Jan. | 1984 | 23,0 | 53 |
| Feb. | | 18,5 | 77,5 |
| March | | 67,5 | 130 |
| April | | 25,5 | 72,0 |

Fig.24. Minimum and maximum temperatures taken over the period of the experiment in the Alexandria District.



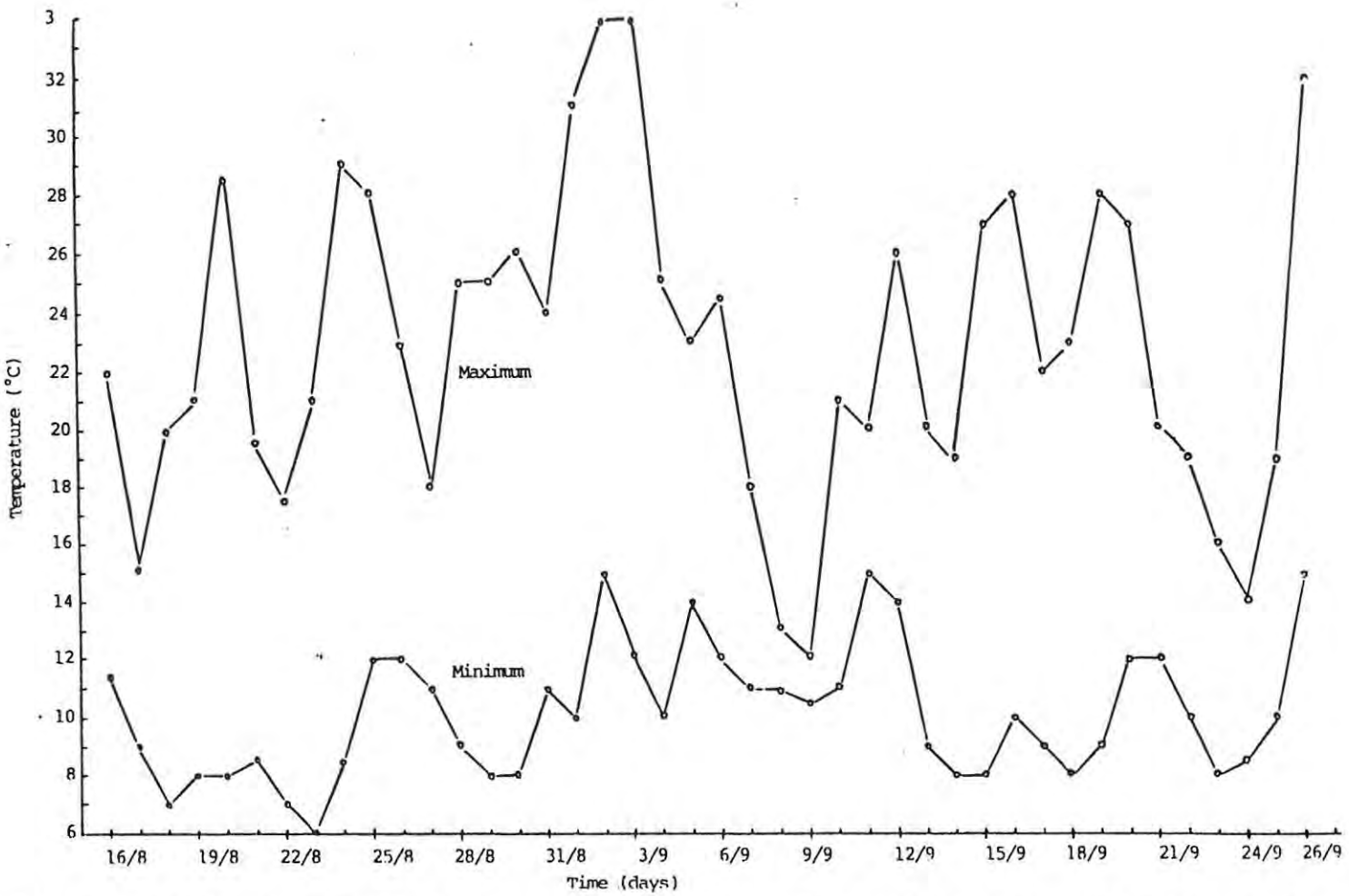



Fig. 25. Minimum and maximum temperatures taken over the period of the cold treatment in the Grahamstown district.

### 4.1.3 Results

None of the roots deteriorated or rotted during the cold treatment period and when they were replanted, after about 4 weeks, all had produced healthy plants. Inflorescences appeared firstly on the 6 and 4 week treatments, and later, inflorescences developed on the controls, indicating that by lifting and later replanting the root, inflorescence formation may be induced.

Fig. 26: **Plants with flowering inflorescences on the right and some plants in the process of producing flowering stalks or peduncles, on the left.**

It was noted that when the leaves of the plants are in an upright position, the plant is in the process of forming an inflorescence (fig. 27), which appeared soon afterwards. The first flowers were produced after approximately 10 weeks on the plants where the roots were given 6 weeks at a constant 4 C temperature, followed by the plants given 6 weeks at 10 C. Later the 4 week and then the 2 week treatments produced flowers (Table 8).

Fig. 27: **Inflorescence of** Cichorium intybus L.

| Treatments * | NO. PLANTED. 29/9/83 | NO. WITH LEAVES. 29/9/83 | Percentage of Plants that grew | | | | | Plants that formed seed stalks (%) | | | | | | | | Plants that flowered (%) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 6/10/83 | 13/10/83 | 20/10/83 | 27/10/83 | 3/11/83 | 10/11/83 | 17/11/83 | 24/11/83 | 1/12/83 | 8/12/83 | 15/12/83 | 22/12/83 | 29/12/83 | | 8/12/83 | 15/12/83 | 22/12/83 | 29/12/83 | 5/ 1/84 | 12/ 1/84 | 19/ 1/84 | 26/11/84 |
| 4 WC 10 S | 15 | - | 53,3 | 93,3 | 100 | 100 | 100 | | 33 | 46,6 | 73 | 80 | 86,6 | 93,3 | 93,3 | - | 6,6 | 46,6 | 53,3 | 60 | 80 | 80 | 80 | 86,6 |
| L | 15 | - | 86,6 | 100 | 100 | 100 | 100 | 6,66 | 6,66 | 20 | 53,3 | 93,3 | 93,3 | 93,3 | 93,3 | - | - | 26,6 | 33,3 | 40 | 73,3 | 80 | 86,6 | 86,6 |
| 2 WC 10 S | 15 | - | 20 | 73,3 | 73,3 | 100 | 100 | - | - | - | 13,3 | 33,3 | 40 | 40 | 40 | - | - | - | 6,6 | 20 | 33,3 | 33,3 | 40 | 46,6 |
| L | 15 | - | 40 | 93,3 | 100 | 100 | 100 | - | - | - | 6,6 | 6,6 | 6,6 | 6,6 | 6,6 | - | - | - | - | - | - | - | 6,6 | 20 |
| 2 WF 4 S | 15 | - | 26,6 | 66 | 93 | 100 | 100 | - | - | 6,6 | 13,3 | 13,3 | 13,3 | 20 | 20 | - | - | 6,6 | 13,3 | 13,3 | 13,3 | 13,3 | 20 | 33,3 |
| L | 15 | - | 60 | 86 | 100 | 100 | 100 | - | - | - | 13,3 | 13,3 | 33,3 | 33,3 | 33,3 | - | - | - | 6,6 | 13,3 | 13,3 | 33,3 | 33,3 | 40 |
| 2 WF 10 S | 15 | - | 53 | 93 | 100 | 100 | 100 | - | - | 6,6 | 13,3 | 13,3 | 13,3 | 13,3 | 13,3 | - | - | 6,6 | 16,6 | 13,3 | 13,3 | 13,3 | 13,3 | 20 |
| L | 15 | 2 | 86 | 93 | 100 | 100 | 100 | - | - | - | - | - | 6,6 | 6,6 | 13,3 | - | - | - | - | - | 6,6 | 6,6 | 13,3 | 13,3 |
| 6 WC 10 L | 15 | 5 | 93 | 100 | 100 | 100 | 100 | 26,6 | 40 | 53,3 | 66,6 | 80 | 86,6 | 86,6 | 86,6 | - | 20 | 46,6 | 46,6 | 60 | 80 | 80 | 80 | 86,6 |
| S | 15 | - | 73 | 100 | 100 | 100 | 100 | - | 13,3 | 33,3 | 73,3 | 86,6 | 86,6 | 86,6 | 86,6 | 6,6 | 6,6 | 26,6 | 40 | 73,3 | 80 | 80 | 86,6 | 86,6 |
| 6 WF 10 L | 15 | 12 | 93 | 100 | 100 | 100 | 100 | - | - | 26,6 | 40 | 40 | 60 | 60 | 66,6 | - | - | 13,3 | 26,6 | 40 | 46,6 | 60 | 73,3 | 80 |
| S | 15 | 12 | 86,6 | 93 | 93 | 100 | 100 | 6,6 | 6,6 | 26,6 | 40 | 60 | 66,6 | 66,6 | 66,6 | 6,6 | 6,6 | 13,3 | 26,6 | 26,6 | 60 | 60 | 66,6 | 73,3 |
| 6 WC 4 L | 15 | - | 60 | 93 | 100 | 100 | 100 | 26,6 | 33,3 | 60 | 86,6 | 93,3 | 93,3 | 93,3 | 93,3 | 6,6 | 20 | 46,6 | 60 | 73,3 | 80 | 80 | 86,6 | 93,3 |
| S | 15 | - | 53 | 93 | 100 | 100 | 100 | - | 6,6 | 26,6 | 60 | 73,3 | 73,3 | 73,3 | 80 | - | - | 26,6 | 33,3 | 46,6 | 66,6 | 73,3 | 73,3 | 86,6 |
| 6 WF 4 L | 15 | 2 | 40 | 80 | 80 | 93 | 100 | 66 | 20 | 46,6 | 46,6 | 53,3 | 60 | 66,6 | 80 | - | - | 33,3 | 40 | 53,3 | 53,3 | 53,3 | 60 | 73,3 |
| S | 15 | 8 | 93 | 93 | 93 | 93 | 100 | - | - | 26,6 | 26,6 | 46,6 | 66,6 | 66,6 | 66,6 | - | - | 13,3 | 26,6 | 40 | 53,3 | 66,6 | 66,6 | 66,6 |
| 6 WContr.L | 15 | 15 | 100 | 100 | 100 | 100 | 100 | 13,3 | 13,3 | 13,3 | 26,6 | 26,6 | 26,6 | 26,6 | 40 | 6,6 | 6,6 | 13,3 | 20 | 26,6 | 26,6 | 33,3 | 40 | 53,3 |
| S | 15 | 15 | 100 | 100 | 100 | 100 | 100 | 6,66 | 6,66 | 6,66 | 20 | 20 | 20 | 20 | 33,3 | - | - | 6,6 | 6,6 | 13,3 | 13,3 | 13,3 | 26,6 | 46,6 |
| 4 WS 4 S | 15 | - | 13 | 60 | 87 | 100 | 100 | 20 | 20 | 40 | 40 | 53,3 | 66,6 | 66,6 | 73,3 | - | 6,6 | 40 | 40 | 46,6 | 53,3 | 53,3 | 60 | 86,6 |
| L | 15 | - | 53 | 93 | 93 | 100 | 100 | 13,3 | 13,3 | 33,3 | 53,3 | 53,3 | 60 | 60 | 60 | - | - | 33,3 | 33,3 | 46,6 | 53,3 | 53,3 | 53,3 | 66,6 |
| 2 WC S | 15 | 3 | 67 | 87 | 100 | 100 | 100 | - | - | - | - | - | 6,66 | 6,66 | 6,66 | - | - | - | - | - | - | - | 6,6 | 20 |
| L | 15 | 5 | 87 | 87 | 87 | 100 | 100 | - | - | - | - | 6,66 | 6,6 | 6,6 | 6,6 | - | - | - | - | 6,6 | 6,6 | 6,6 | 13,2 | 20 |
| 4 WF 4 S | 15 | - | 20 | 33 | 67 | 93 | 100 | - | 6,6 | 20 | 26,6 | 40 | 40 | 40 | 46,6 | - | - | 20 | 20 | 20 | 20 | 20 | 26,6 | 53,3 |
| L | 15 | - | 73 | 93 | 93 | 93 | 105 | 6,6 | 13,3 | 13,3 | 26,6 | 40 | 60 | 60 | 60 | - | 6,6 | 13,3 | 26,6 | 26,6 | 40 | 40 | 60 | 66,6 |
| 2 WC 4 S | 15 | - | 7 | 53 | 67 | 87 | 100 | - | - | - | 13,3 | 20 | 20 | 20 | 33,3 | - | - | - | - | 13,3 | 20 | 20 | 20 | 53,3 |
| L | 15 | - | 20 | 80 | 93 | 100 | 100 | - | - | - | - | 13,3 | 20 | 20 | 33,3 | - | - | - | - | 6,6 | 13,3 | 13,3 | 26,6 | 26,6 |
| 4 WF 10 S | 15 | 3 | 47 | 53 | 93 | 93 | 100 | - | - | 6,6 | 40 | 60 | 60 | 60 | 66,6 | - | - | 6,6 | 13,3 | 26,6 | 53,3 | 53,3 | 73,3 | 73,3 |
| L | 15 | 12 | 100 | 100 | 100 | 100 | 100 | - | - | 6,6 | 40 | 40 | 46,6 | 46,6 | 60 | - | - | 13,3 | 13,3 | 33,3 | 40 | 40 | 53,3 | 60 |
| 4 WC S | 15 | 13 | 93 | 100 | 100 | 100 | 100 | - | - | 6,6 | 6,6 | 6,6 | 13,3 | 13,3 | 13,3 | - | - | - | 6,6 | 6,6 | 6,6 | 6,6 | 13,3 | 20 |
| L | 15 | 14 | 100 | 100 | 100 | 100 | 100 | - | - | 20 | 26,6 | 33,3 | 40,0 | 40 | 40 | - | - | 13,3 | 20 | 33,3 | 33,3 | 33,3 | 40 | 53,3 |

TABLE 8: The effect of cold treatment on the flowering of Chicory.

* KEY.
2 WC - Two weeks constant
2 WF - Two weeks fluctuating
4 WC - Four weeks constant
4 WF - Four weeks fluctuating
6 WC - Six weeks constant
6 WF - Six weeks fluctuating
S - Small
L - Large

The highest percentage flowering (93,3%) was recorded for the large roots kept at a constant temperature of 4 °C for 6 weeks. Overall, the roots kept at constant temperatures gave a higher percentage of flowering than those subjected to fluctuating temperatures. The roots treated at 10 °C were kept in a cold room at Alexandria, where the outside minimum temperature fluctuated between 5 and 17 °C, and the maximum 14 - 33,5 °C during this time period (Fig. 24). The roots treated at 4 °C were kept in a cold room at the Department of Plant Sciences, Grahamstown. The minimum outside temperatures fluctuated between 6 °C and 15 °C, and the maximum between 12 and 34 °C (Fig. 25), leaving little or no difference in the fluctuating temperatures between the two areas Very little difference in flowering was recorded between the large roots at 4 and 6 weeks, stored at 4 and 10 °C (Table 8, Figs. 28 and 29).

**TABLE 9: 3-WAY ANALYSIS OF VARIANCE TABLE - showing the effects of three factors, time, size and cold, on flowering.**

| Source of variation | df | SS | MS | Fs |
|---|---|---|---|---|
| A Time (T) | 2 | 4091,49 | 2045,75 | 69,75 *** |
| B Size (S) | 1 | 2,20 | 2,20 | 0,08 ns |
| C Treatments (Tr) | 4 | 1719,05 | 429,76 | 14,65 *** |
| A x B | 2 | 137,67 | 68,84 | 2,35 ns |
| A x C | 8 | 480,64 | 60,08 | 2,05 ns |
| B x C | 4 | 265,42 | 66,36 | 2,26 ns |
| A x B x C | 8 | 234,64 | 29,33 | |
| Total | 29 | 6931,11 | | |

ns = not significance
*** = probability < 0,001

From the 3-way analysis of variance table (Table 9), it was found that significant results were obtained between the time stored and cold treatments applied to the roots. These results were then analysed by way of a 4-way

Analysis of Variance Test (Table 10), separating the cold treatments into temperature, and constant/fluctuating temperatures. In this case the only significant differences were betwen the different time periods for which the roots were given cold treatments. This would indicated that in the 3-way Anova test, the significance for treatments was due to differences in fluctuating and constant treatments (see Figs. 28 and 29).

**TABLE 10: ANALYSIS OF VARIANCE TABLE - showing the effects of the 4 factors, time, size, cold and constant/fluctuating temperatures, on flowering.**

| Source of variation | df | SS | MS | Fs |
|---|---|---|---|---|
| A Time | 2 | 3966,93 | 1983.47 | 52,14 ⁎ |
| B Size | 1 | 41,03 | 41,03 | 1,08 ns |
| C Temperature | 1 | 4,07 | 4,07 | 0,11 ns |
| D Constant/Fluctuating | 1 | 534,12 | 534,12 | 14,04 ns |
| A x B | 2 | 136,92 | 68,46 | 1,80 ns |
| A x C | 2 | 190,98 | 95,49 | 2,51 ns |
| A x D | 2 | 36,17 | 18,09 | 0,48 ns |
| B x C | 1 | 11,95 | 11,95 | 0,31 ns |
| B x D | 1 | 85,88 | 85,88 | 2,26 ns |
| C x D | 1 | 2,97 | 2,97 | 0,08 ns |
| A x B x C | 2 | 3,24 | 1,62 | 0,04 ns |
| A x B x D | 2 | 48,28 | 24,14 | 0,63 ns |
| A x C x D | 2 | 63,96 | 31,98 | 0,84 ns |
| B x C x D | 2 | 38,52 | 38,52 | 1,01 ns |
| A x B x C x D | 1 | 76,07 | 38,04 | |
| Total | 23 | 5241,09 | | |

⁎ Probability < 0,1
* Probability < 0,05
** Probability < 0,01
*** Probability < 0,001
ns not significant

The rainfall for the period, January, 1983 to December, 1983, gave a monthly average of 61,1 mm, compared to a monthly average of 75,3 mm (Table 7), taken for the same period over 60 years. Although it gave a slightly lower rainfall than the 60 year average, it was sufficient for normal growth and development.

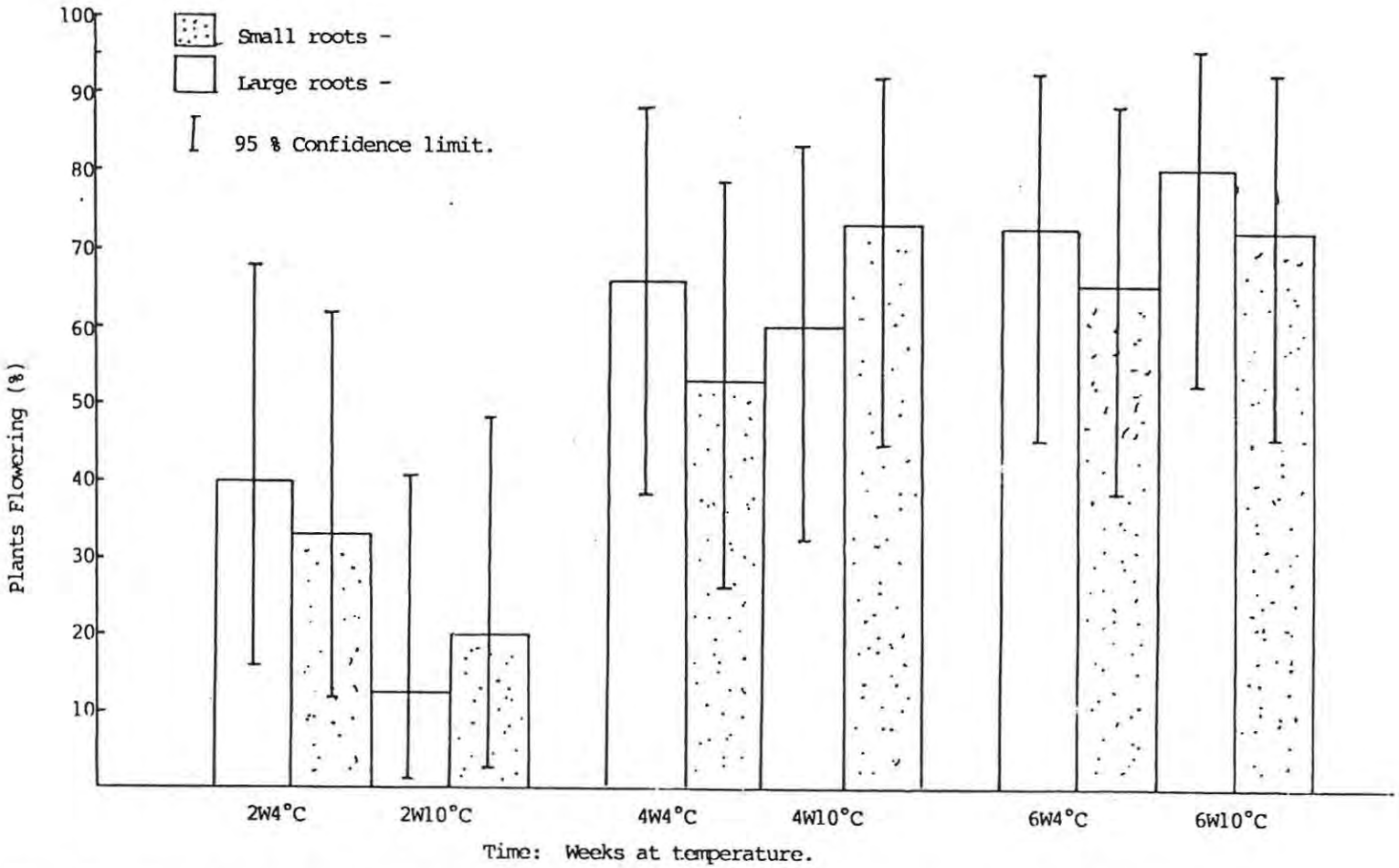



Fig. 28. Mean percentage flowering of chicory plants under influence of fluctuating temperatures and varying storage time of roots.

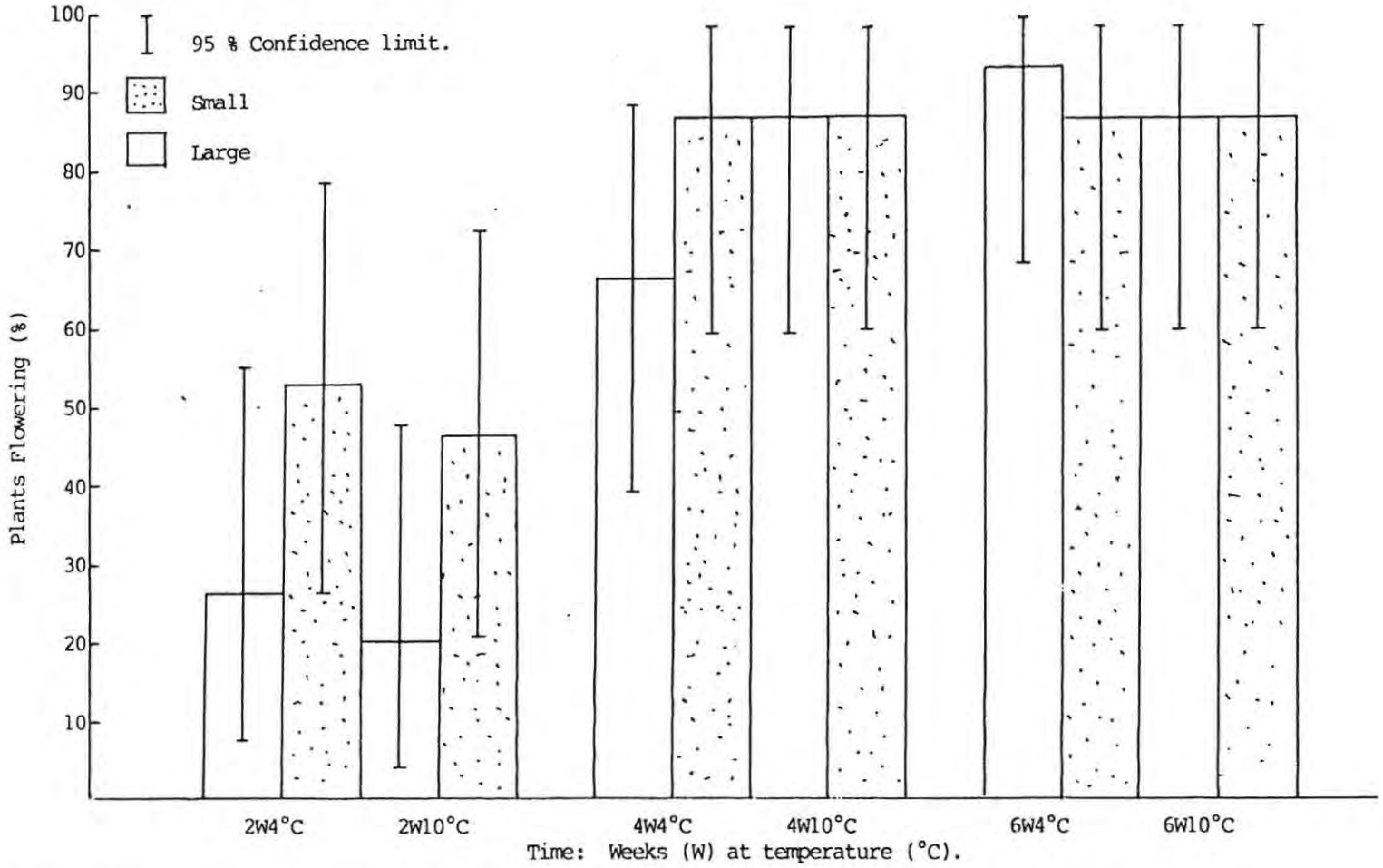



Fig. 29. Mean percentage flowering of chicory plants under influence of constant temperature and varying storage time of roots.

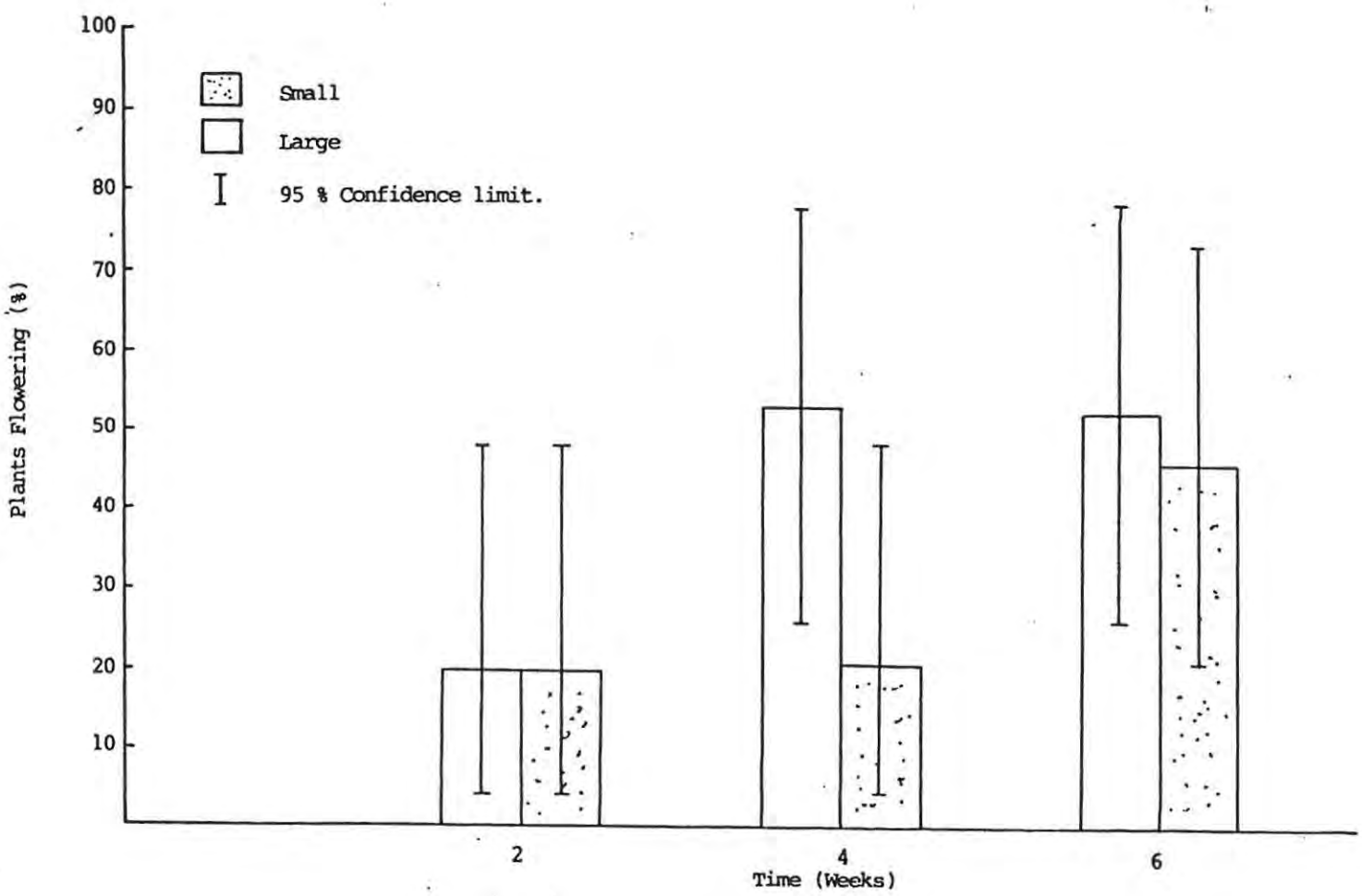



Fig. 30. Control - Mean percentage chicory plants flowering after roots had been left outside for different lengths of time.

When reaping the seed, it was found that the large roots formed more flowering stalks than the small roots. The two week treatments gave an average of 1,8 flower stalks per plant for the large roots, and 1,6 for the small roots. The four weeks treatment yielded 3,5 and 2,5 flower stalks per plant and the six week treatment gave 3,5 and 2,8 flower stalks per plant. There was little difference in the amount of flower stalks formed at 4 and 6 week treatments, whilst these were close to double that of the 2 week treatments. The higher number of flower stalks on the large roots resulted in a higher seed yield per plant, giving a mean of 6,7g/plant for large, and 3,9g/plant for the small plants. The 6 and 4 week treatments gave higher seed yields/plant than that of the 2 week treatments, but differed little from each other. The 4 and 6 week treatments gave a mean of 6,1g/plant and the 2 week treatment gave a mean of 2,8g/plant.

**4.1.4 Discussion**

From the results obtained it was found that, although there was little difference in the flowering of small and large roots, it would be preferable to use larger and more mature roots when replanting, since more flowering stalks form on larger roots, resulting in a higher seed yield per plant. From Fig. 29, it can also be said that storage of roots at 4 and 10 °C for a constant period of 4 weeks would be sufficient to ensure a flowering percentage of 80 . Although this method might sound very time consuming, it is effective in forcing chicory to flower. A great deal of seed can be lost through flowering stalks not developing simultaneously. This concept needs further incestigation and the possibility of a hormone treatment at a certain stage in the development of the flowering stalk could be a possible method of forcing the stalks to emerge more uniformly.

These results of seed yield were obtained by reaping once at the end of the experiment. It must be kept in mind that in practice, seed is reaped weekly over a period of 4 months. If the seed was reaped in this manner for the purpose of the experiment, a much higher yield per plant would have been achieved, and the possibility exists that the yield per plant might even be doubled.

The seed yield results of between 3,9g/plant for small roots and 6,7g/plant for large roots, as obtained from this experiment compares well with that done in the Karoo region where four farmers were each given 7000 roots and achieved seed yields of 7 kg, 22 kg and 47,8 kg, giving an average of 1g, 3,14g and 6,71 g/plant (Aucamp and Mai, 1981).

**Fig. 31: The Capitulum of Cichorium intybus L.**

Another experiment done in Queenstown in 1980/81, with differing root sizes and planting dates, gave average seed yields of between 8 and 15g/plant (Aucamp and Mai, 1981). If taken into account that in this experiment the seed was not reaped at the correct intervals, a seed yield per plant of 6,7g is still within reach, and could be increased to approximately 13,4g if reaped correctly.

## 4.2 THE EFFECT OF CYTOKININ SPRAYS ON FLOWERING AND ROOT PRODUCTION OF CHICORY PLANTS

### 4.2.1 Introduction

Cytokinins are plant growth regulators which control or influence virtually all growing processes in the plant. They were discovered in 1954, in tissue culture studies of tobacco pith, at the laboratories of Folke Skoog at the University of Wisconsin.

Schraudolf and Reinert (1959) found that Begonia leaf cuttings treated with kinetin, developed buds all along the edge, whereas normally, buds develop only at the basal end of the main veins. The leaves of some species, including certain kinds of Begonias, that do not naturally form buds and roots on cuttings can be induced to do so by treatments with cytokinins. Harris and Hart (1964) found that cytokinins inhibited bud initiation in **Peperomia sandersii**, except in isolated cases where exceptionally high concentrations were used.

The object of this study is to determine whether or not commercially available cytokinins might increase flowering in **Cichorium intybus L.** or have any other significant influences on the normal growth thereof.

### 4.2.2 Materials and methods

The product used in this experiment was **Kelpak 66**, containing natural cytokinins from **Ecklonia maxima** ... 0,031mg/l. Kelpak 66 is a seaweed foliar spray manufactured in Cape Town. It is different from other seaweed foliar sprays in that it is manufactured by a unique cell burst process which does not involve the use of heat, chemicals, freezing or dehydration. Only freshly

harvested seaweed is used and the process ensures that the delicate growth regulators present in the seaweed are not destroyed. Kelpak 66 is the only seaweed product which has been registered as a growth stimulant in this country. Presently, the registration is for use on wheat, tomatoes and flowering plants (Christie, 1984).

The chicory was planted in a sandy soil on the farm Dekselfontein in the Alexandria district. The plants were sprayed with Kelpak 66, at 3 months of age. The spraying of 2 litres Kelpak 66 per hectare in 300 litres water per hectare was undertaken on the 5/1/84, 26/1/84 and 16/2/84. The experiment was lifted on the 9 May 1984.

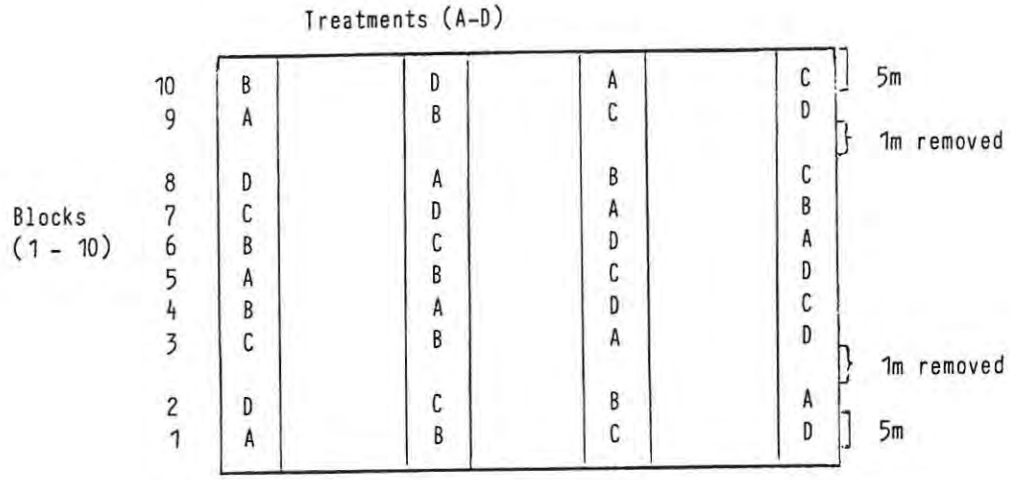
The treatments were as follows:

| | | | |
|---|---|---|---|
| A | - on | 5/1/84 | - 1 spraying |
| B | - on | 5/1/84 and 26/1/84 | - 2 sprayings |
| C | - on | 5/1/84, 26/1/84 and on 16/2/84 | - 3 sprayings |
| D | - control, not sprayed at all | | |

Ten replications of 4 rows x 5 metres per treatment were measured out, leaving three rows between plots as guard rows. The treatments were randomized with each replication.

Before the experiment was lifted, one metre (as shown in experimental layout) of plants with each row between the plots were removed to prevent the possibility of spray drift which might have occurred. The number of plants which flowered in each plot as well as the total number of roots and root weight per plot was calculated.

Experimental layout:




## 4.2.3 Results

### 4.2.3.1 Flowering

**TABLE 11:** The percentage of roots that flowered with three different spray treatments.

| Blocks | Spray Treatment | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 spray | | | 2 sprays | | | 3 sprays | | | No spray | | |
| | no. roots | plants flowered | % | no. roots | plants flowered | % | no. roots | plants flowered | % | no. roots | plants flowered | % |
| 10 | 196 | 4 | 2 | 225 | 7 | 3,1 | 221 | 2 | 0,9 | 215 | 2 | 0,9 |
| 9 | 226 | 6 | 2,2 | 212 | 4 | 1,9 | 141 | 3 | 2,1 | 219 | 2 | 0,9 |
| 8 | 175 | 1 | 0,6 | 198 | 8 | 4,0 | 209 | 4 | 1,9 | 264 | 4 | 1,5 |
| 7 | 191 | 9 | 4,7 | 173 | 4 | 2,3 | 161 | 2 | 1,2 | 240 | 4 | 1,6 |
| 6 | 185 | 7 | 3,8 | 148 | 5 | 3,4 | 219 | 5 | 2,3 | 214 | 8 | 3,7 |
| 5 | 191 | 8 | 4,2 | 220 | 7 | 3,2 | 152 | 7 | 4,6 | 179 | 6 | 3,4 |
| 4 | 121 | 9 | 7,4 | 156 | 9 | 5,8 | 115 | 7 | 6,0 | 142 | 13 | 9,1 |
| 3 | 180 | 16 | 8,9 | 107 | 7 | 6,5 | 137 | 7 | 5,1 | 132 | 4 | 3,0 |
| 2 | 167 | 2 | 1,2 | 163 | 9 | 5,5 | 103 | 10 | 9,7 | 276 | 2 | 0,7 |
| 1 | 151 | 6 | 4,0 | 168 | 3 | 1,8 | 160 | 8 | 5,0 | 178 | 5 | 2,8 |
| Total | 1783 | 68 | 3,9 | 1770 | 63 | 3,7 | 1618 | 55 | 3,8 | 2059 | 50 | 2,7 |
| 95% confidence interval | | 53-86 | | | 48-81 | | | 41-72 | | | 37-66 | |

No marked differences could be seen in the leaf growth of the plants when they were lifted. The application of Kelpak 66 by spraying, had no marked influences on the flowering (Table 11). Although a slightly higher percentage flowering was obtained in the treatments compared with the control, there was no difference between percentage flowering for those of the one, two or three spray treatments.

#### 4.2.3.2 Root yield

The mean number of roots per plot was about 200 (Table 11) so all weights were converted to the weight (kg) per 200 roots (Table 12)

**TABLE 12:** Mean weight (kg) per 200 roots

| Blocks | Spray Treatment | | | | |
|---|---|---|---|---|---|
| | One Spray | Two Sprays | Three Sprays | No Spray | Mean |
| 1 | 12,245 | 14,902 | 16,290 | 15,814 | 14,813 |
| 2 | 15,929 | 17,925 | 22,695 | 15,982 | 18,133 |
| 3 | 15,429 | 14,646 | 15,311 | 13,258 | 14,661 |
| 4 | 18,848 | 15,607 | 27,329 | 15,833 | 19,404 |
| 5 | 14,054 | 23,649 | 16,438 | 20,093 | 18,559 |
| 6 | 17,801 | 15,000 | 18,421 | 13,408 | 16,158 |
| 7 | 17,190 | 17,949 | 14,783 | 22,535 | 18,114 |
| 8 | 20,556 | 24,299 | 28,978 | 15,151 | 19,746 |
| 9 | 14,970 | 22,086 | 25,243 | 9,783 | 18,021 |
| 10 | 19,205 | 18,452 | 23,125 | 15,730 | 19,128 |
| Mean | 16,623 | 18,451 | 19,861 | 15,759 | |
| Estimated mean in T/ha | 12,47 | 13,84 | 14,90 | 11,82 | |
| % increase over control | 5,5 | 17,1 | 26,0 | | |

It can be deduced from Table 11 that 3 sprays of Kelpak 66 gave a substantial increase of 26% over the control plants. This increase is shown in Figure 32, which compares one sample, sprayed 3 times with Kelpak 66, against a control sample.

Figure 32: Treated sample, sprayed 3 times with Kelpak 66, against control.


An analysis of variance (Table 13) was performed on the data.

TABLE 13: ANALYSIS OF VARIANCE TABLE - showing the effects of Kelpak spray treatments.

| Source | df | SS | MSS | F |
|---|---|---|---|---|
| Blocks | 9 | 121,09 | 13,454 | 1,04 ns |
| Treatment | 3 | 101,62 | 33,875 | 2,61 * |
| Error | 27 | 350,00 | 12,963 | |
| Total | 39 | | | |

SE = 3,600
CV = 20,37%
LSD 2 Treatment means = 3,30 kg at the 5% level

### 4.2.4 Discussion

From these results, although significant increases in flowering are not achieved by spraying with Kelpak, it can be concluded that a better and healthier root can be produced for the purpose of seed production.

With the results obtained it can be concluded that Kelpak 66 significantly increased the yield of chicory. It is worth noting that some of the roots were heavily infested with root-knot nematodes. It has been proven that Kelpak 66 can substantially reduce root-knot nematode in tomato plants and this ability may have assisted in the trial, as chicory lands infested with nematodes, usually result in a low root yield per hectare.

## 4.3 THE EFFECT OF GIBBERELLIC ACID SPRAYS ON THE FLOWERING OF CHICORY PLANTS

### 4.3.1 Introduction

The discovery of the gibberellins began in 1926 when a Japanese plant pathologist secured an extract from **Gibberella fujikuroi**, an ascomycetous fungus parasite on rice, that greatly stimulated the growth of rice and corn seedlings (Brian, 1966; Leopold, 1964; Stowe, 1959).

Over 30 different gibberellins have been identified and all of them have the same complex skeletal construction, called a gibbane. Since the gibberellins are acids, they are often referred to as gibberellic acid (GA). Most plants contain several different gibberellins, but no plant has been found to contain all of them. If the specific GA is not indicated it is usually assumed to be GA 3.

It is known that GA levels in plants are sensitive to light, photoperiod and temperature (Bukovac and Wittwer, 1957; Lockhart, 1957; Vlitos and Meudt, 1957; Wittwer and Bukovac, 1957). GA is known to have various physiological influences on plants (Brian, 1966; Wittwer and Bukovac, 1958) such as:

- extensive stem elongation
- development of parthenocarpic fruits in some species
- breaking of dormancy
- germination of light requiring seeds
- flower induction

Reproductive growth is not stimulated in all plants. Some need a cold treatment or have a photoperiodic requirement for flower initiation as well as for bolting. Gibberellins are also effective in flower initiation in some,

but not all, non-rosette long-day species, and there have been scattered reports that they promote earlier blooming in some day-neutral plants. However, they are ineffective in causing short-day plants to bloom under long days (Lang, 1957). The various gibberellins differ greatly in their effect on flower initiation. GA 7 is apparently the most generally effective one, and GA 3 is ineffective in many species. It is possible that in species where GA 3 applications promote flowering, the plants can convert it into GA 7 or another gibberellin that promotes flower initiation.

Harrington, Rappaport and Hood (1957) and Wittwer and Bukovac (1957) showed marked stem elongation and flower promotion in **Cichorium endiva**, after apical treatments of 50 to 450 g per plant, or eight weekly applications of 100 g at the 7 to 10 leaf stage. This effect occurred in plants grown under long or short photoperiods and at temperatures ranging from 10 to 18 °C, but was most marked at the higher temperatures and long photoperiod.

Harrington and Rappaport (1957) working with **Daucus carota.** cv sativa, and Morgan, Mees (1958) and Wittwer, Bukovac, Sell, Weller (1957) working with lettuce (**Lactuca sativa** and **Lactuca dentata**), found that treatments with gibberellic acid promoted accelerated seed stalk formation and flowering.

The object of this study is to find a commercial product which is freely available and relatively cheap, which would promote flowering in young chicory plants in order to enable us to initiate floral differentiation.

### 4.3.2 Materials and methods

This experiment was carried out on normal plants spaced for root production, on the farm Dekselfontein. The chicory seedlings emerged on the 6/8/83, and

the immature plants were sprayed on 26/10/83, 2/11/83 and 9/11/83. The treatments were:

| | | | |
|---|---|---|---|
| A | 125 ppm Berelex | x | 3 sprays |
| B | 250 ppm Berelex | x | 3 sprays |
| c | control | - | no spray |

Three replicates per treatment were used, with the experimental blocks measuring 1 m x 3 m. Insects appeared during the development of the flowers, but no insecticides were used, to prevent the possibility of such sprays having and influence on the bolting of the chicory plants and also to avoid interference in normal pollination. Rainfall records were kept. The experiment was lifted on 13/2/84. The same experiment was carried out on 12 month old chicory which had not bolted due to a favourable growing season. The number of plants per plot and the amount that formed flowering shoots and flowered, were calculated. The seed of the plot was reaped, weighed and tested for germination viability.

**4.3.3 Results.**

Unfortunately, the plants that were sprayed at 12 months of age were accidentally lifted a week after the third spraying, due to it being part of a production land. The plants were inspected for any signs of flower initiation, and it was found, as can be seen in figures 33 and 34, that the treated roots (marked 'A' in the figure) had already formed a stalk, though no sign was present in the untreated plants (marked 'B' in the figure).

Fig. 33. Apex and basal leaves of the chicory root sprayed with Berelex (A) and untreated (B)

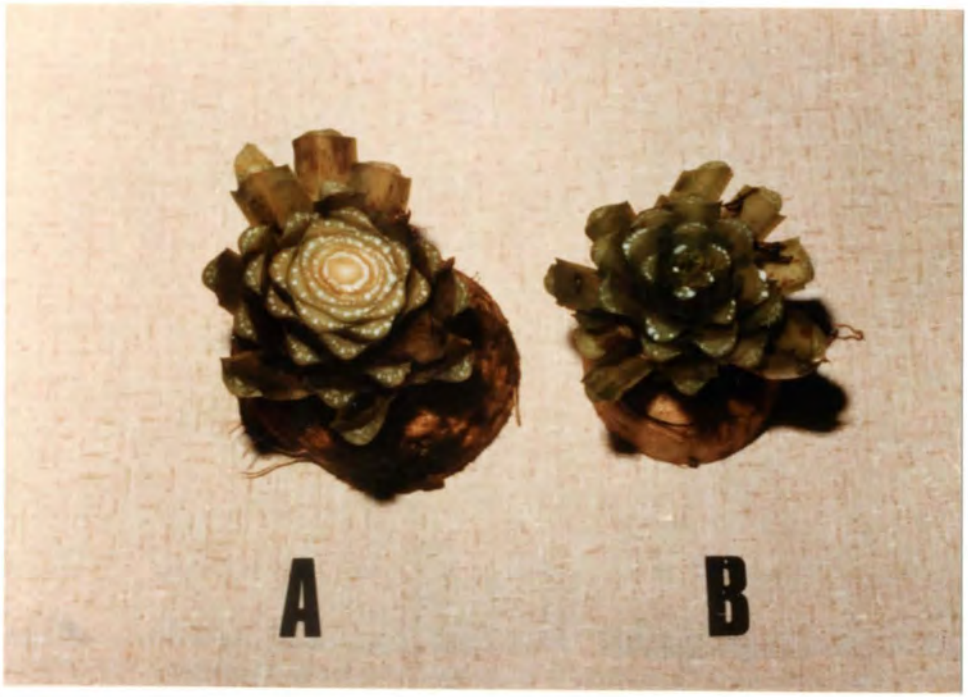



Fig. 34: Longitudinal section of the apex of a root of a chicory plant sprayed with Berelex (A) and untreated (B).

A B

It was found that 96% of the plants treated with 250 ppm GA and 86,6% treated with 125 ppm GA formed flowering stems. There was no sign of flower initiation in the control (Fig. 35).

Fig. 35: **Base of leaves and apex of the control plants showing no flower initiation.**


**TABLE 14. Results of flowering and seed production of young plants sprayed at 125 ppm and 250 ppm GA.**

| Treatments | | Reps. | Plants/ Plot | % stalks | plants flowered | % flowering | 95% confident limits | Total seed (g) | Yield g/ plant | Av. seed weight per 100 | % Germination |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 125 ppm | 1 | 39 | 100 | 17 | 43,6 | 28-60 | 17,2 | 1,01 | 0,098 | 51,6 |
| | | 2 | 22 | 100 | 13 | 59,0 | 36-79 | 16,2 | 1,25 | 0,101 | 54 |
| | | 3 | 32 | 100 | 6 | 18,8 | 7-36 | 5,3 | 0,89 | 0,100 | 35 |
| | Mean | | 31 | 100 | 12 | 40,5 | 22-58 | 12,9 | 1,05 | 0,99 | 46,8 |
| | 250 ppm | 1 | 21 | 100 | 11 | 52,3 | 30-74 | 10,9 | 0,99 | 0,105 | 48 |
| | | 2 | 29 | 100 | 10 | 34,5 | 18-54 | 8,6 | 0,86 | 0,094 | 41 |
| | | 3 | 30 | 100 | 13 | 43.3 | 25-62 | 5,9 | 0,45 | 0,090 | 41,6 |
| | Mean | | 26,6 | 100 | 11,3 | 43,3 | 23-63 | 8,4 | 0,76 | 0,096 | 43,5 |

Figure 36 shows the three stages in which the flower stalks developed. The lower stage forms a rosette on the stalk resulting in no inflorescence. In the second or middle stage in some cases, inflorescences were formed. The highest stage showed no rosette forming.

Fig. 36: **Three stages of flower development, after spraying with gibberellic acid. (see text)**

### 4.3.4 Discussion

It has been observed that the low temperature requirement of some long-day plants can be satisfied by treating the apical meristem with gibberellic acid. However, gibberellins cause the flowering stem to elongate first and the flower buds are formed later, whereas in a vernalized plant flower buds are formed before the stem elongates.

Successful results were obtained on 12 month old chicory plants treated with 250 ppm GA. In fact 96% of the plants formed flowering stems.

In the 3 month old plants, although they all (100%) formed flowering stems, only about 40% of the plants developed a complete inflorescence (Table 14). The reason for this is attributed to the fact that the second and third spray might have damaged the apical meristem, or a reverse effect could possibly have taken place.

The seed yield per plant and the germination percentage was below average (Table 14 - and compare with section 3 on germination). This indicated that immature plants, although they form inflorescences, can not be forced to produce seed of the same quantity and quality as in the case of a normal mature plant grown under favourable conditions for seed production.

From these results, it can be concluded that, by treating mature chicory plants with GA, it is possible to induce a high degree of uniformity in floral differentiation. This in turn opens the way for mechanical harvesting of chicory seed, which in itself is a major breakthrough, since seed is hand reaped at present, due to the plants flowering over an extended period of up to 3 months.

## 5. GENERAL CONCLUSIONS

Although chicory does not have an absolute requirement of fluctuating temperatures for germination, results showed an optimum germination with temperatures fluctuating between 20 °C and 26 °C. Whether constant or fluctuating, favourable germination percentages should be obtained, depending on the cultivar sown and the inherent germinative capacity of the seed. Luxor seed was found to withstand higher temperatures more favourably than Wixor and Pevele.

The pericarp colour gave no significant differences, although the darker seeds gave higher germination percentages than the pale seeds. The reason for the variation in seed colour may be somewhat complex, but could possibly be related to: seasonal variations, temperature/humidity conditions at ripening, position of the flower on the raceme, and possibly even inherent characteristics of individual plants.

Water uptake in relation to seed density, as was tested in this experiment has no marked influence on the germination of chicory seed. Although the germination of chicory seed might be stimulated in the early stages it is not dependent on light or darkness for germination.

The greatest percentage of seedling emergence was found for seeds sown at a depth of between ½cm and 2 cm. The soil type and environmental factors such as temperature and availability of moisture would influence this factor.

It was found that by treating the roots with cytokinins, better and bigger roots were produced, which, in turn form more inflorescences per plant. A

cold treatment of four weeks at 10 °C was sufficient to force the roots to form flowering stalks. Even by removing the mature roots and replanting after a few weeks, it was found that the plants produced inflorescences. By treating mature chicory plants with gibbrellic acid, it was possible to induce a high degree of uniformity in floral differentiation, which opens the way to mechanical harvesting of chicory seed.

The problem of seed production in South Africa, and especially in the Alexandria district, may be overcome by using the results of experiments obtained in this study. Some aspects need further investigations.

Appendix 1. **Minimum and maximum temperature and humidity recordings, taken by means of a thermohygrograph, over the period 18/8/83 - 18/1/84 in the Alexandria district.**

| | Temperature (°C) | | | Humidity (%) | | |
|---|---|---|---|---|---|---|
| Date | Max. Temp. | Min. Temp. | Mean | Max. | Min. | Mean |
| 18/8/83 | 14 | 9 | 11,5 | 98 | 70 | 84 |
| 19/8/83 | 16,5 | 10 | 13,25 | 96 | 55 | 75,5 |
| 20/8/83 | 19,5 | 9 | 14,25 | 96,5 | 37 | 66,75 |
| 21/8/83 | 22,5 | 10,9 | 16,7 | 97 | 39 | 68 |
| 22/8/83 | 16 | 8 | 12 | 85,5 | 48,5 | 67 |
| 23/8/83 | 17 | 5 | 11 | 97,5 | 45 | 71,25 |
| 24/8/83 | 20 | 7 | 13,5 | 98 | 32 | 65 |
| 25/8/83 | 22,5 | 14 | 18,25 | 60 | 30 | 45 |
| 26/8/83 | 19 | 10 | 14,5 | 96,5 | 70,5 | 83,5 |
| 27/8/83 | 18 | 11 | 14,5 | 94 | 62,5 | 78,25 |
| 28/8/83 | 19 | 8 | 13,5 | 92 | 27 | 59,5 |
| 29/8/83 | 15 | 9 | 12 | 94,5 | 60 | 77,25 |
| 30/8/83 | 24,5 | 7,5 | 16 | 98 | 25 | 61,5 |
| 31/8/83 | 20 | 11 | 15,5 | 97 | 45 | 71 |
| 1/9/83 | 24,8 | 10 | 17,4 | 96,5 | 36 | 66,25 |
| 2/9/83 | 33,5 | 14 | 23,75 | 85 | 28 | 56,5 |
| 3/9/83 | 28 | 13 | 20,5 | 94 | 28 | 61 |
| 4/9/83 | 18 | 10 | 14 | 90 | 48 | 69 |
| 5/9/83 | 24 | 14 | 19 | 96 | 36 | 66 |
| 6/9/83 | 20 | 12 | 16 | 96,5 | 49 | 72,75 |
| 7/9/83 | 20 | 12 | 16 | 97 | 70 | 83,5 |
| 8/9/83 | 15 | 12 | 13,5 | 96,5 | 78 | 174,5 |
| 9/9/83 | 16 | 12 | 14 | 96 | 77,5 | 86,75 |
| 10/9/83 | 20,8 | 13 | 16,9 | 95 | 78 | 86,5 |
| 11/9/83 | 22 | 15 | 18,5 | 95,5 | 47,5 | 71,5 |
| 12/9/83 | 22 | 13 | 35 | 90 | 45,0 | 67,5 |
| 13/9/83 | 16,5 | 10 | 13,25 | 91 | 52,0 | 71,5 |
| 14/9/83 | 18,0 | 7 | 12,5 | 90 | 49,0 | 69,5 |
| 15/9/83 | 21,0 | 8 | 29 | 95 | 39,0 | 67 |
| 16/9/83 | 22,0 | 10,9 | 16,40 | 97 | 35,0 | 66 |
| 17/9/83 | 19,0 | 10,0 | 14,5 | 88 | 46 | 67 |
| 18/9/83 | 19,5 | 8 | 13,75 | 95 | 47 | 71 |
| 19/9/83 | 24 | 17 | 20,5 | 80 | 31 | 55,5 |
| 20/9/83 | 20 | 13 | 16,5 | 94,5 | 47 | 70,75 |
| 21/9/83 | 24 | 14 | 19 | 97 | 40 | 68,5 |
| 22/9/83 | 18 | 11 | 14,5 | 93 | 52 | 72,5 |
| 23/9/83 | 19,5 | 9,5 | 14,5 | 92 | 57 | 74,5 |
| 24/9/83 | 16 | 10 | 13 | 96 | 58 | 77 |
| 25/9/83 | 18 | 11 | 14,5 | 96 | 54 | 75 |
| 26/9/83 | 27 | 14 | 20,5 | 95 | 34 | 64,5 |
| 27/9/83 | 20 | 12 | 16 | 92 | 62,5 | 77,25 |
| 28/9/83 | 24 | 14 | 19 | 92 | 59 | 75,5 |
| 29/9/83 | 23,5 | 13 | 18,25 | 96 | 54 | 75 |
| 30/9/83 | 26 | 14 | 20 | 95,5 | 58 | 76,75 |

Appendix 1 - continued

| Temperature (°C) | | | | Humidity (%) | | |
|---|---|---|---|---|---|---|
| Date | Max. Temp. | Min.Temp. | Mean | Max. | Min. | Mean |
| 1/10/83 | 29 | 11 | 20 | 94 | 40 | 67 |
| 2/10/83 | 18 | 11,5 | 14,75 | 95,8 | 83 | 89,4 |
| 3/10/83 | 19 | 10 | 14,5 | 95 | 67 | 81 |
| 4/10/83 | 14 | 10,5 | 12,25 | 95 | 57 | 76 |
| 5/10/83 | - | - | | 96 | 66 | 81 |
| 6/10/83 | - | - | | 95 | 58 | 76,5 |
| 7/10/83 | - | - | | 97 | 60 | 78,5 |
| 8/10/83 | 33 | 13 | 23 | 95,5 | 40 | 67,75 |
| 9/10/83 | 37 | 12 | 24,5 | 96 | 23,5 | 59,75 |
| 10/10/83 | 23 | 16 | 19,5 | 94 | 66 | 80 |
| 11/10/83 | - | - | | 94 | 72 | 83 |
| 12/10/83 | - | - | | 95 | 48 | 71,5 |
| 13/10/83 | - | - | | 94 | 54 | 74 |
| 14/10/83 | 24 | 16 | 20 | 92 | 65,5 | 78,75 |
| 15/10/83 | 19,5 | 14 | 16,75 | 95 | 70 | 82,5 |
| 16/10/83 | - | - | | 95 | 46,5 | 70,75 |
| 17/10/83 | 24 | 13 | 18,5 | 93 | 58 | 75,5 |
| 18/10/83 | - | - | | 95 | 42,5 | |
| 19/10/83 | 25 | 12,5 | 18,75 | 89 | 46,5 | 67,75 |
| 20/10/83 | 29 | 12 | 20,5 | 94 | 49 | 71,5 |
| 21/10/83 | 26,5 | 11 | 37,5 | 94 | 63 | 78,5 |
| 22/10/83 | 31 | 14 | 22,5 | 93 | 40 | 66,5 |
| 23/10/83 | 26 | 13 | 19,5 | 93 | 50 | 71,5 |
| 24/10/83 | 23 | 9,2 | 16,1 | 95 | 45 | 70 |
| 25/10/83 | 27 | 7,5 | 17,25 | 95 | 42,5 | 68,75 |
| 26/10/83 | 31,5 | 8,5 | 20 | 95 | 24,5 | 59,75 |
| 27/10/83 | 31 | 11 | 21 | 95 | 34,8 | 64,9 |
| 28/10/83 | 36,5 | 12 | 24,5 | 94 | 34 | 64 |
| 29/10/83 | 27 | 12,5 | 19,75 | 92,5 | 45,2 | 68,85 |
| 30/10/83 | 24 | 12 | 18 | 94,5 | 46 | 70,25 |
| 31/10/83 | 25,5 | 13,5 | 19,5 | 85 | 37,5 | 61,25 |
| 1/11/83 | 28 | 10 | 19 | 92,5 | 40 | 132,5 |
| 2/11/83 | 30,8 | 10 | 20,4 | 92,5 | 44 | 68,25 |
| 3/11/83 | 34 | 14 | 24 | 92 | 46 | 69 |
| 4/11/83 | 31 | 17 | 24 | 92 | 50 | 71 |
| 5/11/83 | 24 | 13,2 | 18,6 | 92 | 65 | 78,5 |
| 6/11/83 | 23 | 12,2 | 17,6 | 92,5 | 47 | 69,75 |
| 7/11/83 | 24,5 | 13 | 18,75 | 95 | 65 | 80 |
| 8/11/83 | 26 | 11,6 | 18,8 | 93 | 52 | 72,5 |
| 9/11/83 | 28 | 10 | 19 | 92 | 42,5 | 67,25 |
| 10/11/83 | 28,5 | 10,5 | 19,5 | 92 | 35 | 63,5 |
| 11/11/83 | 22 | 13 | 17,5 | 92 | 49 | 70,5 |
| 12/11/83 | 28 | 11 | 19,5 | 92,5 | 40 | 66,25 |
| 13/11/83 | 33 | 11 | 22 | 93 | 32 | 62,5 |
| 14/11/83 | 29 | 13 | 21 | 91 | 40 | 65,5 |
| 15/11/83 | 31,5 | 11 | 21,25 | 93 | 37,5 | 65,25 |

Appendix 1 - continued

| Date | Temperature (℃) | | | Humidity (%) | | |
|---|---|---|---|---|---|---|
| | Max. Temp. | Min. Temp. | Mean | Max. | Min. | Mean |
| 16/11/83 | 34 | 13 | 23,5 | 93 | 37,5 | 65,25 |
| 17/11/83 | 24,5 | 20 | 22,25 | 92,5 | 71 | 81,75 |
| 18/11/83 | 30 | 20 | 25 | 92,5 | 67,5 | 80 |
| 19/11/83 | 31 | 20 | 25,5 | 92,5 | 55 | 73,75 |
| 20/11/83 | 31,5 | 22 | 26,75 | 92,5 | 44 | 68,25 |
| 21/11/83 | 29 | 18 | 23,5 | 92 | 57,5 | 74,75 |
| 22/11/83 | 32 | 16,5 | 24,25 | 94 | 51 | 72,5 |
| 23/11/83 | 35 | 16 | 25,5 | 94 | 40 | 67 |
| 24/11/83 | 35 | 16 | 25,5 | 93,5 | 42,5 | 68 |
| 25/11/83 | 24,5 | 18 | 21,25 | 92,5 | 76 | 84,25 |
| 26/11/83 | 31 | 13 | 22 | 92,5 | 40 | 66,25 |
| 27/11/83 | 31 | 18 | 24,5 | 92,5 | 49 | 70,75 |
| 28/11/83 | 33,5 | 20 | 26,75 | 88 | 40 | 64 |
| 29/11/83 | 36 | 18 | 27 | 94 | 42 | 68 |
| 30/11/83 | 34,5 | 19,5 | 27 | 95 | 42 | 68,5 |
| 1/12/83 | 38 | 18,5 | 28,25 | 95 | 41 | 68 |
| 2/12/83 | 32 | 17 | 24,5 | 93,5 | 38 | 65,75 |
| 3/12/83 | 33 | 12 | 22,5 | 95 | 35 | 65 |
| 4/12/83 | 36 | 15,5 | 25,75 | 94 | 42,5 | 68,25 |
| 5/12/83 | 44 | 21,4 | 32,7 | 96 | 22 | 59 |
| 6/12/83 | 34 | 19,6 | 26,8 | 93 | 41 | 26,8 |
| 7/12/83 | 33 | 17,5 | 50,5 | 94 | 39 | 66,5 |
| 8/12/83 | 23 | 16,5 | 19,75 | 94,5 | 75 | 84,75 |
| 9/12/83 | 30 | 16 | 23 | 94 | 57 | 75,5 |
| 10/12/83 | 36 | 15 | 25,5 | 94 | 40 | 67 |
| 11/12/83 | 38 | 16,5 | 27,25 | 94 | 41 | 67,5 |
| 12/12/83 | 33,5 | 18 | 25,75 | 93,5 | 46 | 69,75 |
| 13/12/83 | 40,5 | 18 | 29,25 | 94,5 | 32,5 | 63,5 |
| 14/12/83 | 40 | 18 | 29 | 93 | 35,5 | 64,25 |
| 15/12/83 | 35 | 20 | 27,5 | 92,5 | 77 | 84,75 |
| 16/12/83 | 43,5 | 19 | 31,25 | 92,5 | 19 | 55,75 |
| 17/12/83 | 19 | 15 | 17 | 94 | 76,5 | 85,25 |
| 18/12/83 | 29,5 | 12 | 20,75 | 92,5 | 52 | 72,25 |
| 19/12/83 | 32 | 17 | 24,5 | 93 | 31 | 62,0 |
| 20/12/83 | 46 | 16 | 31 | 94 | 37,5 | 65,75 |
| 21/12/83 | 38 | 20,5 | 29,25 | 93 | 42,5 | 67,75 |
| 22/12/83 | 37 | 20 | 28,5 | 94 | 42 | 68 |
| 23/12/83 | 39,5 | 16,5 | 28 | 94,5 | 35,5 | 65 |
| 24/12/83 | 40 | 18,5 | 29,25 | 94 | 36,5 | 65,25 |
| 25/12/83 | 38 | 16 | 27 | 94,5 | 35 | 64,75 |
| 26/12/83 | 38 | 16 | 27 | 92 | 25 | 58,5 |
| 27/12/83 | 41 | 15 | 28 | 93 | 31,5 | 62,25 |
| 28/12/83 | 46 | 17 | 31,5 | 94 | 22,5 | 58,25 |
| 29/12/83 | 34,5 | 30 | 32,25 | 92,5 | 51 | 71,75 |
| 30/12/83 | 30 | 29,5 | 29,75 | 93 | 40,5 | 66,75 |
| 31/12/83 | 39 | 29,5 | 34,25 | 93 | 27,5 | 60,25 |

Appendix 1 continued.

| Temperature (°C) | | | | Humidity (%) | | |
|---|---|---|---|---|---|---|
| Date | Max. Temp. | Min. Temp. | Mean | Max. | Min. | Mean |
| 1/ 1/84 | 40 | 19 | 29,5 | 93,5 | 27 | 60,25 |
| 2/ 1/84 | 34 | 16,5 | 25,25 | 93,5 | 36,5 | 65 |
| 3/ 1/84 | 43,5 | 15 | 29,25 | 92 | 18,5 | 54,75 |
| 4/ 1/84 | 39 | 18,5 | 28,75 | 94 | 32 | 63 |
| 5/ 1/84 | 39 | 20 | 29,5 | 92,5 | 27 | 59,75 |
| 6/ 1/84 | 30,5 | 20 | 25,25 | 95 | 55 | 75 |
| 7/ 1/84 | 32 | 20 | 26 | 94,5 | 37 | 65,75 |
| 8/ 1/84 | 37,5 | 20 | 28,75 | 94,5 | 35 | 64,75 |
| 9/ 1/84 | 43 | 20 | 31,5 | 92,5 | 35 | 63,75 |
| 10/ 1/84 | 44 | 17,5 | 61,5 | 94,5 | 23 | 58,75 |
| 11/ 1/84 | 40 | 18 | 29 | 94 | 22 | 58 |
| 12/ 1/84 | 27,5 | 16 | 21,75 | 92,5 | 45 | 68,75 |
| 13/ 1/84 | 31,5 | 15,5 | 23,5 | 92,5 | 31 | 61,75 |
| 14/ 1/84 | 37 | 18 | 27,5 | 87 | 26 | 56,5 |
| 15/ 1/84 | 45 | 15 | 30 | 92 | 15 | 53,5 |
| 16/ 1/84 | 41 | 15 | 28 | 92 | 15,5 | 53,75 |
| 17/ 1/84 | 44 | 19,5 | 31,75 | 92 | 24 | 58 |
| 18/ 1/84 | 36,5 | 19 | 27,75 | 92 | 27,5 | 59,75 |

Appendix 2. **Minimum and maximum temperature and humidity recordings taken over the period 16/8/83 - 26/9/83, in the Grahamstown area.**

| | Temperature (°C) | | | Humidity (%) | | |
|---|---|---|---|---|---|---|
| Date | Max. Temp. | Min. Temp. | Mean | Max. | Min. | Mean |
| 16/ 8/83 | 22 | 11,5 | 16,75 | 90 | 25 | 57,5 |
| 17/ 8/83 | 15 | 9 | 12 | 94 | 65 | 79,5 |
| 18/ 8/83 | 20 | 7 | 13,5 | 97 | 45 | 71 |
| 19/ 8/83 | 21 | 8 | 14,5 | 95 | 35 | 65 |
| 20/ 8/83 | 28,5 | 8 | 18,25 | 83 | 20 | 51,5 |
| 21/ 8/83 | 19,5 | 8,5 | 14 | 85 | 35 | 60 |
| 22/ 8/83 | 17,5 | 7 | 12,25 | 95 | 55 | 75 |
| 23/ 8/83 | 21 | 6 | 13,5 | 90 | 40 | 65 |
| 24/ 8/83 | 29 | 8,5 | 18,75 | 90 | 25 | 57,5 |
| 25/ 8/83 | 28 | 12 | 20 | 68 | 30 | 49 |
| 26/ 8/83 | 23 | 12 | 17,5 | 87 | 45 | 66 |
| 27/ 8/83 | 18 | 11 | 14,5 | 95 | 62 | 78,5 |
| 28/ 8/83 | 25 | 11 | 17 | 95 | 20 | 57,5 |
| 29/ 8/83 | 25 | 9 | 16,5 | 95 | 25 | 60 |
| 30/ 8/83 | 26 | 8 | 17 | 95 | 24 | 59,5 |
| 31/ 8/83 | 24 | 11 | 17,5 | 90 | 30 | 60 |
| 1/ 9/83 | 31 | 10 | 20,5 | 95 | 30 | 62,5 |
| 2/ 9/83 | 34 | 15 | 24,5 | 68 | 18 | 43 |
| 3/ 9/83 | 34 | 12 | 23 | 95 | 22 | 58,5 |
| 4/ 9/83 | 25 | 10 | 11,6 | 90 | 30 | 60 |
| 5/ 9/83 | 23 | 14 | 18,5 | 87 | 35 | 61 |
| 6/ 9/83 | 24,5 | 12 | 18,25 | 88 | 38 | 63 |
| 7/ 9/83 | 18 | 11 | 14,5 | 97 | 73 | 85 |
| 8/ 9/83 | 13 | 11 | 12 | 97 | 92 | 94,5 |
| 9/ 9/83 | 12 | 10 | 11,25 | 96 | 95 | 95,5 |
| 10/ 9/83 | 21 | 11 | 16 | 95 | 64 | 79,5 |
| 11/ 9/83 | 20 | 15 | 17,5 | 90 | 46 | 68 |
| 12/ 9/83 | 26 | 14 | 20 | 86 | 38 | 62 |
| 13/ 9/83 | 20 | 9 | 14,5 | 75 | 45 | 60 |
| 14/ 9/83 | 19 | 8 | 13,5 | 87 | 45 | 66 |
| 15/ 9/83 | 27 | 8 | 17,5 | 90 | 28 | 59 |
| 16/ 9/83 | 28 | 10 | 19 | 94 | 28 | 61 |
| 17/ 9/83 | 22 | 9 | 15,5 | 81 | 35 | 58 |
| 18/ 9/83 | 23 | 8 | 15,5 | 90 | 42 | 66 |
| 19/ 9/83 | 28 | 9 | 18,5 | 80 | 30 | 60 |
| 20/ 9/83 | 27 | 12 | 19,5 | 95 | 46 | 70,5 |
| 21/ 9/83 | 20 | 12 | 16 | 97 | 53 | 75 |
| 22/ 9/83 | 19 | 10 | 14,5 | 90 | 55 | 72,5 |
| 23/ 9/83 | 16 | 8 | 12 | 87 | 60 | 73,5 |
| 24/ 9/83 | 14 | 8,5 | 11,2 | 95 | 65 | 80 |
| 25/ 9/83 | 19 | 10 | 14,5 | 95 | 58 | 76,5 |
| 26/ 9/83 | 32 | 15 | 23,5 | 75 | 24 | 49,5 |

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