

## CHAPTER 8

### EFFECT OF SOME PLANT FACTORS ON TUBER GROWTH

#### 8.1 EFFECT OF LEAF NUMBER / AREA

##### 8.1.1 Introduction

Under appropriate environmental conditions plants such as potato, sweet potato and beetroot divert most of the assimilates being produced into reproductive storage organs. It would seem logical to assume that the larger the leaf area on the plant at that stage the greater the amount of assimilates available for transport to the storage organs, and so the greater the yield. This statement does not, however, appear to hold true for all species of plants.

Decreasing the leaf area of plants has been reported to decrease storage organ yields in cassava, sweet potato, radish and onions (Kato, 1965; Jackson, 1980; Dahniya, 1981; Dahniya, Oputa & Hahn, 1981; Gonzales *et al.*, 1983). Contrary to expectations, storage organ formation in some varieties of Brassica's (*Brassica oleracea*) and in taro (*Colocasia esculenta*) has been increased by defoliation, while the effect of this practice on yields of beet (*Beta vulgaris*) have proved inconsistent (Selman & Kulasegaram, 1967; Humphries, 1971; Das Gupta, 1972; Abit & Alferez, 1979).

As early as the middle of the 20<sup>th</sup> century it was claimed to be possible to increase the yields of both sugar beet and main crop potatoes by planting earlier in order to obtain larger leaf areas at the time tuber bulking commenced (Watson, 1952). However, it is not only assimilate production that is affected by leaf area, but also the production of the so-called "tuberisation stimulus". One of the major problems in using plants to investigate the tuberisation response in potato has been the effect of plant size, as it can be expected that a plant with many leaves will manufacture and transport much more of this stimulus than a smaller plant will (Ewing, 1981; Kahn, Ewing & Senesac, 1983). This effect was

demonstrated by removing leaves from apical cuttings of potato and measuring percentage tuberisation. There proved to be a very good correlation between the leaf number on the cuttings and the percentage tuberisation which took place (Perennec, 1966, Ewing, 1981). Lemaga & Caesar (1990) showed that the number of main stems and leaf area were positively correlated with tuber number and tuber yield of potatoes, although the leaf area had a smaller effect than number of main stems. They did find, however, that plants with the smallest leaf area consistently produced the lowest yields.

In their work with potato cuttings Kahn *et al.* (1983) demonstrated that leaf area and tuberisation were correlated, and that reducing the leaf area reduced the tuberisation response. They also found that tuber dry mass declined with declining leaf area, confirming the findings of Edward (1969). Leaf age has also been shown to be important in tuberisation in potato, as a small leaf area consisting of young, expanding and fully expanded leaves provided stronger tuberisation than a larger area of older, more senescent leaves (Kahn *et al.*, 1983).

Cranshaw & Radcliffe (1980) found only slight reductions in potato yields when plants had between 40 and 67% of their leaves removed. This would appear to be inconsistent with the idea that leaf area plays an important role in the determination of final yields in potato. However, work with leaf cuttings of sweet potato demonstrated that only half of the leaf lamina was required for maximum tuberisation, and removal of more than 50% of the leaf resulted in proportionately lower yields (Sihachakr *et al.*, 1982). It could therefore be that potato plants react in the same way as sweet potatoes to the loss of leaf area.

The objective of this experiment was to determine the effect of cutting size (leaf area) on tuber mass.

### 8.1.2 Materials and Methods

This trial was carried out at the University of Pretoria's phytotron facility located on the experimental farm in Hatfield, Pretoria, in the facilities described in **Chapter 5**. All plants

were exposed to inductive conditions (10 hours light at a 25/17°C day/night temperature regime) in a Conviron controlled environment chamber for a period of 28 days.

After this inductive period plants were removed from the the growth chamber and a number of different treatments applied. The various treatments consisted of cuttings with different numbers of leaves, ranging from 2 to 10 leaves per cutting, in multiples of two due to there being two leaves per node in this species. This means that the cuttings ranged in length from two to six nodes. The cuttings were taken by cutting the stem below the first above-ground node, and again midway between the required node and the one above it (Figure 8.1). For example on a two-node cutting the second cut was made midway between nodes two and three. Similarly, to produce a six-node cutting the second cut was made midway between nodes six and seven. The lowest pair of leaves was removed from the cutting, which was then planted in the same way as described in **Chapter 5**.

The trial was arranged in the air-conditioned glasshouse described in **Chapter 5**, a fully randomised design with nine replicates. After a period of 28 days for tuber growth to take place, the cuttings were harvested and photographed. The number of leaves, leaf area, leaf mass, occurrence of tubers and tuber mass were recorded.

Standard analyses of variance, together with correlation analyses were carried out on the data.

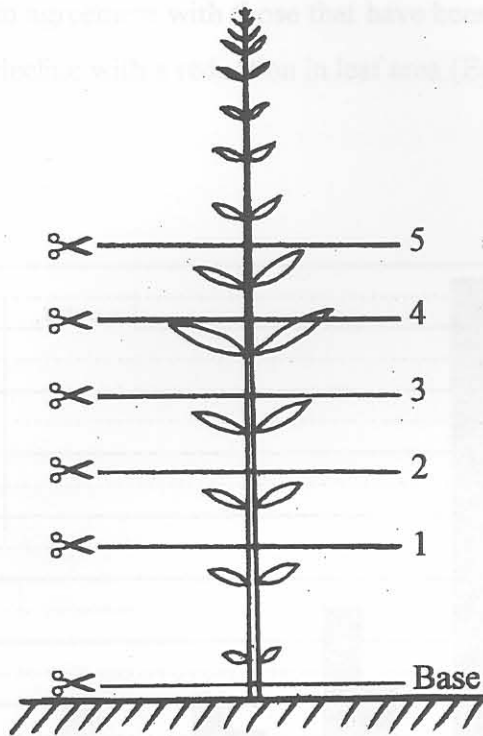
### 8.1.3 Results and Discussion

#### Tuberisation

All the cuttings in this experiment showed signs of tuber induction in the form of tuber buds on the swollen bases of the underground shoots after the 28 days exposure to inductive conditions. Differences were, however, noted in the percentage of cuttings exhibiting tubers, with only 68% of the two leaf cuttings having visible tuber development rather than tuber buds. All of the cuttings with greater numbers of leaves had visible tuber development of varying size. This might be related to the age of the leaves on the short cutting, as Kahn *et*



*al.* (1983) found that older, more senescent leaves gave weaker tuberisation than younger leaves in potato cuttings.



**Figure 8.1** Schematic representation of cutting procedure

Key: ✂ Position of cut

Base First cut

1 Two leaf cutting

2 Four leaf cutting

3 Six leaf cutting

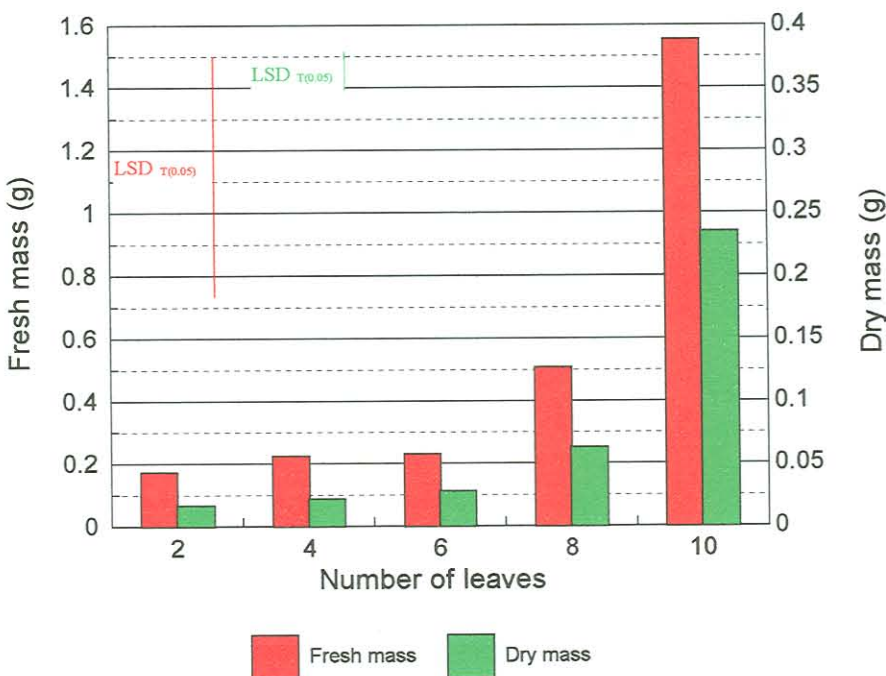
4 Eight leaf cutting

5 Ten leaf cutting

The mass of the tubers was significantly affected by the number of leaves on the cutting,

with tubers on 10 leaf cuttings significantly heavier than those on shorter cuttings (Figure 8.2). No statistical differences in tuber mass occurred between cuttings with two, four, six or eight leaves.

The results appear to be in agreement with those that have been found on potato, where tuber mass was found to decline with a reduction in leaf area (Edward, 1969; Kahn *et al.*, 1983).



**Figure 8.2** Effect of leaf area (represented by number of leaves) on the tuber mass produced by *Plectranthus esculentus* cuttings

### Growth

#### Shoots

Differences in the average aerial shoot length occurred between the various treatments, with aerial shoots on cuttings with 10 leaves being significantly shorter than those of any other cuttings (Table 8.1). The length of aerial shoots found on cuttings with two to eight leaves did not differ significantly from each other. The masses of these shoots, both fresh and dry,

reflected the difference in shoot length, with significant differences being found between the various cuttings (Table 8.1). The mass of shoots from cuttings with 10 leaves was significantly higher than those from cuttings with two to six leaves. The mass of shoots from cuttings with eight leaves did not differ statistically from those of any of the other cuttings.

The underground shoots from the two leaf cuttings were significantly longer and had a significantly higher fresh mass than those produced on any of the other cuttings (4 to 10 leaves).

TABLE 8.1 Effect of cutting length on aerial and underground shoots

Length of cutting (leaf pairs)	Shoot length (mm)		Shoot mass (g)			
			Fresh		Dry	
	Aerial	Underground	Aerial	Underground	Aerial	Underground
1	9.84	15.70	0.101	0.198	0.0136	0.0174
2	11.75	3.50	0.129	0.075	0.0198	0.0075
3	12.03	0.01	0.136	0.001	0.0256	0.0001
4	8.22	5.40	0.062	0.058	0.0121	0.0070
5	1.51	2.30	0.020	0.009	0.0037	0.0013
LSD <sub>(0.05)</sub>	5.94	9.54	0.085	0.137	0.0129	ns

ns - not significant

### Leaves

The increase in leaf area from 58.13cm<sup>2</sup> found on the six leaf cuttings (Table 8.2) to the 107.87cm<sup>2</sup> found on the eight leaf cuttings shows that the leaves on the fourth node above the soil surface are a great deal larger than those found closer to the soil surface. The first three pairs of leaves had very similar areas, ranging from 19 to 24cm<sup>2</sup>. On the fourth and fifth nodes, however, the average leaf area showed a dramatic increase, with the leaf area on the cuttings almost doubling from node three to node four, and increasing by more than

one-third again from node four to node five. This shows that the largest leaves are in the central to upper portion of the stem.

TABLE 8.2 Leaf area and mass as affected by length of cutting

Length of cutting (leaf pairs)	Leaf area (cm <sup>2</sup> )	Leaf mass (g)	
		Fresh	Dry
1	24.07	0.174	0.017
2	47.41	0.226	0.022
3	58.13	0.232	0.028
4	107.87	0.508	0.063
5	145.78	1.554	0.235
LSD <sub>(0.05)</sub>	34.20	1.668	0.1875

The mass of the leaves, both fresh and dry, was also highly significantly affected by the cutting type (Table 8.2). A pattern similar to that of leaf area was found, with the exception that the mass of leaves on the eight leaf cutting was not statistically different from that obtained on the 10 leaf cutting. The leaf mass of these two cuttings was, however, significantly greater than that obtained on the other three cuttings (two, four and six). The leaf mass of the latter cuttings did not differ significantly. The leaves on node five appeared to be thinner than those found on node four as their masses do not differ significantly, even though the areas do. This apparent difference will have to be tested in future experiments.

Leaves in the middle portion of the stem are larger than those found towards the base of the plant. This increase in leaf size is coupled with an increase in tuber mass, and this can possibly be attributed not only to the increase in leaf area, but also the leaf age. Kahn *et al.* (1983) in their work on potatoes found that leaf age, and not just the leaf area, played an important role in tuberisation with a small leaf area consisting of young fully expanded



leaves providing stronger tuberisation than a larger area of older more senescent leaves. In the case of *Plectranthus* the older leaves at the base of the stem are not only smaller, but also thicker than the younger leaves found higher on the stem. Observations of cuttings made from both old and young cuttings in potatoes showed that cuttings with older leaves appeared to be more likely to tuberise than those with small leaves from the same plant (Ewing, 1978). Kahn *et al.* (1983), however, found that the middle leaves on the potato stem were very effective in increasing the total percentage of cuttings that tuberised, while the oldest leaves had the least effect. A similar reaction could possibly have occurred in this case. This should be tested, but some results could no doubt be obtained when looking at the effect of node position on the stem on tuberisation in this species.

If the partitioning of dry matter in the intact plant parallels that in cuttings, then at a given level of induction a larger leaf area increases the percentage of dry matter distributed to the tubers. This implies that plants that have put on a greater leaf area during the season prior to induction taking place will produce higher total yields in a similar way to potatoes as was postulated by Watson (1952). It is believed that it would be better to plant slightly larger tuber portions of *Plectranthus*, even if this results in a slightly smaller area being planted, in order to obtain multistem plants, leading to higher total yields being obtained from the planting. Allen & Scott (1980), demonstrated that the leaves on multi-stemmed potato plants were better arranged spatially to intercept radiation, and that this resulted in increased yields. The leaf area of the potato plant has also been shown to have a smaller effect on final yields than the number of main stems (Lemaga & Caesar, 1990). This is something that would need to be tested in *P. esculentus*.

#### 8.1.4 Conclusions

Leaf area plays a definite role in the growth of tubers in this species, with a greater tuber mass being produced on cuttings with a greater leaf area.



## 8.2 EFFECT OF NODE POSITION ON TUBER GROWTH OF CUTTINGS

### 8.2.1 Introduction

*Plectranthus esculentus* plants exhibit a pattern of tuberisation similar to that observed on potato plants, with the most basipetal nodes responding most strongly to tuber induction. This pattern of tuberisation in potato has been noted on intact plants (Plaisted, 1957; Lovell & Booth, 1969; Gray, 1973; Wurr, 1977), on sections from sprouts (Mingo-Castle, Smith & Kumamoto, 1976), and on stem cuttings (Gregory, 1956; Chapman, 1958). Kumar & Wareing (1972) found that stolon development was also normally restricted to the base of the potato plant. Evidence has been presented by a number of researchers that stolon emergence and development is similar to tuberisation in that it is strongest at the older, lower nodes of the plant (Plaisted, 1957; Lovell & Booth, 1969; Gray, 1973; Wurr, 1977).

It has been proved beyond doubt that the tuberisation stimulus in potato is hormonal in nature (Hammes & Nel, 1975; Menzel, 1985b; Koda *et al.*, 1988), and that the point of reception of the induction stimulus is in the leaves (Hammes & Beyers, 1973; Menzel, 1985a). Early studies suggested that the predominant movement of this stimulus in the potato was in a basipetal direction, from the leaves to the buried buds, suggesting that gravitational movement was responsible for this pattern of tuberisation (Gregory, 1956; Chapman, 1958). However, later work showed that the stimulus could move both acropetally and basipetally (Okazawa & Chapman, 1962; Kumar & Wareing, 1973). Observations of *P. esculentus* plants appeared to indicate that acropetal movement of the tuberisation stimulus took place, with the first tubers on the plants being induced at the lowest point on the stem, and then being produced at points higher up the stem as the exposure periods to inductive conditions increase. Evidence has also been presented that tuber development in potatoes occurred at the lowest nodes of stem cuttings, irrespective of their physical orientation (Kumar & Wareing, 1973; Kahn & Ewing, 1983).

It has been postulated that this greater tuberisation in the basal portion of the potato plant could be ascribed to the proximity of the mother tuber (Plaisted, 1957, Gray, 1973, Mingo-Castle *et al.*, 1976). Although both Gregory (1956) and Chapman (1958) showed that tuberisation first occurred at the base of stem cuttings even in the absence of the mother

tuber, a lingering effect of the mother tuber has been suggested (Madec & Perennec, 1962). Kahn & Ewing (1983) showed that the proximity of the mother tuber had no effect on this pattern of tuberisation in potato.

The age of buds did not appear to play a role in tuberisation, as tubers could form from buds on stem cuttings that would not normally develop into tubers (Kumar & Wareing, 1972; Ewing, 1985; Ewing & Struik, 1992). This also appears to be the case in *Plectranthus esculentus*, where aerial tubers have been observed developing from axial buds throughout the length of the stem, and even terminal growth points have developed into tubers under favourable conditions.

It appears as though stem cuttings can be taken from any portion of the stem in order to investigate tuberisation. However, a number of researchers have found that cuttings from either the middle nodes or the younger nodes gave the strongest tuberisation (Lawrence & Barker, 1963; Simmonds, 1965; Forsline & Langille, 1976; Ewing, 1978; Kahn *et al.*, 1983). Results from earlier research carried out with *P. esculentus* indicate that tuberisation is better when younger leaves are included on the cutting (**Chapter 8.1**), although this might just be due to the increase in leaf area.

The objective of this experiment was to determine if node position on the stem affected tuberisation in *Plectranthus*, so assisting in determining the best cuttings to use in tuberisation studies. A secondary objective was to attempt to determine how far up the stem the tuber induction stimulus had spread after an induction period of 28 days.

## 8.2.2 Results and Discussion

### Tuberisation

#### 8.2.2 Materials and Methods

The plants and facilities used in this experiment are described in **Chapter 5**. Plants were exposed to inductive conditions of short days (10 hours light) at a 25/17°C day/night temperature regime in a Conviron controlled environment chamber for a period of 28 days. After this period plants were removed from the growth chamber and cut into a number of two-node cuttings as described in **Chapter 5**. The first cutting (number 1) consisted of the

first two nodes on the plant. The second cutting consisted of nodes number three and four, and so on up the stem of the plant. At this stage it was possible to make a minimum of nine two-node cuttings from each plant.

In order to simplify the discussion the following protocol will be used to refer to cuttings from the various positions on the stem:

- Cutting 1 - nodes one and two
- Cutting 2 - nodes three and four
- Cutting 3 - nodes five and six
- Cutting 4 - nodes seven and eight
- Cutting 5 - nodes nine and ten

Pot preparation and planting of cuttings took place as described in **Chapter 5**. After planting the pots were placed in an air-conditioned glasshouse for tuber growth and development to take place. The pots were arranged out in a fully randomised design replicated 11 times.

After 21 days the cuttings were harvested and photographed. Leaf area, leaf mass, shoot length, shoot mass, tuber length and tuber mass were recorded, together with all signs of tuber induction having taken place (swollen bases of underground shoots, tuber buds and tubers). This data was then subjected to statistical analyses.

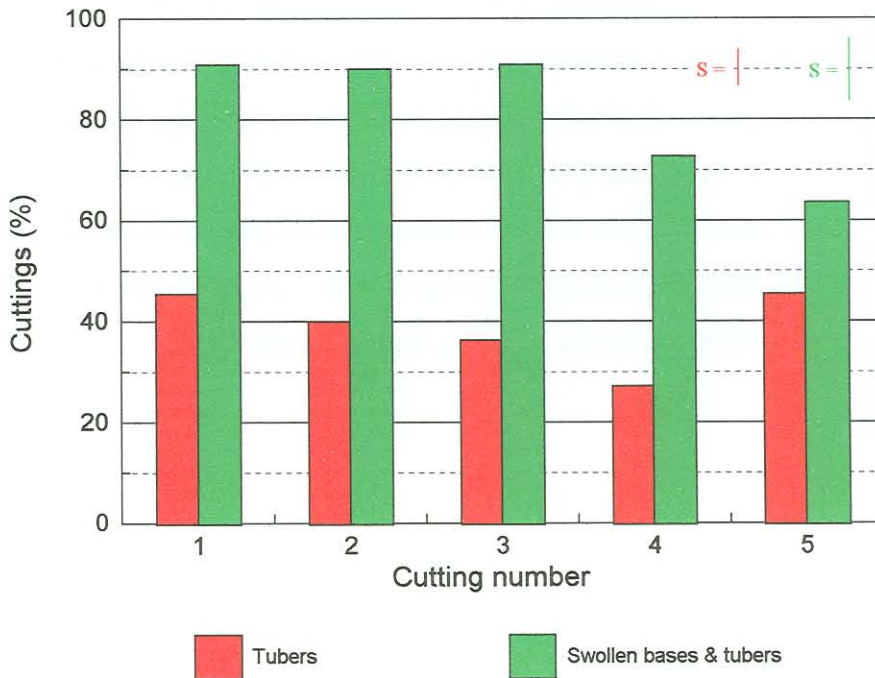
### 8.2.3 Results and Discussion

#### Tuberisation

No statistically significant differences for tuber length, or mass (fresh and dry) occurred between the various treatments. This indicates that the stem portion from which the cuttings are taken does not influence tuberisation in this species. Potato cuttings, on the other hand, showed a tendency for the fresh mass of the tuber to increase when the bud was located at an increasingly basal position (Kahn & Ewing, 1983). The number of cuttings exhibiting swollen bases to underground shoots, as well as those cuttings with tubers were calculated



as a percentage of the total number of cuttings per treatment (Figure 8.3).



**Figure 8.3** Percentage of treated cuttings showing signs of tuber formation or tuber induction

Figure 8.3 shows that approximately 90% of the cuttings from the lower portion of the stem (nodes one to six) showed signs of tuber induction. Cuttings 4 and 5 (nodes seven to ten) showed a reduced incidence of tuber induction. The percentage of cuttings with tuber development showed a declining tendency as the distance from the base increased. The increase in the percentage of cuttings with tubers on the cuttings from nodes nine and ten cannot be explained at this stage. However, it would appear that the tuberisation stimulus moves in an acropetal direction in the stem once tuberisation starts, and that bud age *per se* was not controlling the pattern of tuberisation. This has also been found in the potato, where tuberisation was found to be stronger in an acropetal direction under certain conditions (Kahn & Ewing, 1983).

These results indicate that it is best to take cuttings from the lower to centre portion of the stem when using cuttings to study tuber induction in this species, a result somewhat different from that obtained in potato studies where it was determined that cuttings from the middle of the stem were the best (Lawrence & Barker, 1963; Simmonds, 1965). However, cuttings 2 and 3 (nodes three to six) show indications of tuber inductions similar to those on cutting 2, and this appears to agree with findings on potato by (Kahn & Ewing, 1983), although the effectiveness of tuberisation on the older stem sections does not concur with their findings in potato. Tuberisation in yam, another species found in tropical Africa, has been found to be greater in cuttings originating from old vines, as those cuttings from young vines tend to develop extensive root and shoot systems prior to initiating swollen roots (Onwueme, 1979).

## Growth

### Shoots

All shoot growth parameters (length, fresh and dry mass) showed highly significant differences with regard to their point of origin on the stem. The shortest shoots (7.9mm) were found on cutting 1 (from the lowest point on the stem), and these were significantly shorter than those found on cuttings from any other section of the stem. The longest shoots (32.4 and 26.7mm) were found on cuttings 4 and 5 - the cuttings from the youngest, upper section of the stem. No differences in shoot length were noted on cuttings 3, 4 or 5.

The dry mass of aerial shoots on cutting one was significantly lower than those on any other cutting. This could be due to growth shifting from the aerial to the underground buds. Ewing & Wareing (1978) observed a similar effect in two-node cuttings from potato plants exposed to inductive conditions. This reduction in growth at the aerial bud of these potato cuttings was greater once tubers had formed on the underground bud. This apparent shift in growth pattern in *Plectranthus* should be tested by conducting similar experiments using a range of exposure periods to inductive conditions.

## Leaves

The smallest leaf area ( $14.01\text{cm}^2$ ) was found on cutting 1, and the largest ( $42.36\text{cm}^2$ ) on cutting 5. The leaf area on cutting 1 was statistically lower than that on any other cutting on the plant. The leaf area on cuttings 4 and 5 was significantly greater than that of cutting 2 as well. The leaf area of cutting 3 did not show any significant difference from that of cutting 2.

The dry mass of the leaves was different between the various cuttings, with the leaf mass from cutting 1 being significantly lower than that of any other cutting on the stem, while the mass of leaves from cuttings 2 to 5 did not differ significantly from each other.

These results indicate that the leaves on cuttings 2 and 3 are thicker than those on the higher cuttings as their leaf area is significantly lower than the others, while their masses do not differ significantly. This confirms visual observations of leaves on the stems of *Plectranthus esculentus*.

### 8.2.4 Conclusions

The best cuttings from *P. esculentus* to use in the investigation of tuberisation and tuber growth appear to be those from the base of the stem. The effect of leaf senescence should, however, be borne in mind when making this selection. Bud age does not appear to play a role in controlling the pattern of tuberisation noted in this species, with tubers being found on both old and young buds, while intermediate buds have not formed tubers.

Acropetal movement of the stimulus appears to take place in *Plectranthus*. Research should be conducted in order to prove beyond doubt that tuber growth takes place in an acropetal direction and that the tuber induction stimulus is transported basipetally, and the controlling factors determined.



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