
STUDIES ON THE GROWTH AND DEVELOPMENT OF CHICORY

(*Cichorium intybus* L.)

Thesis submitted in part fulfilment of the requirements for the
Degree of Doctor of Philosophy in Horticulture
to the Tamil Nadu Agricultural University
Coimbatore



By **C. M. PAPPIAH** M.Sc. (Ag.)

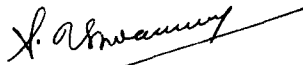
DEPARTMENT OF POMOLOGY AND OLERICULTURE
FACULTY OF HORTICULTURE
TAMIL NADU AGRICULTURAL UNIVERSITY
COIMBATORE - 641 003
1983

CERTIFICATE

This is to certify that the thesis entitled "STUDIES ON THE GROWTH AND DEVELOPMENT OF CHICORY (*Cichorium intybus* L.)" submitted in part fulfilment of the requirements for the degree of DOCTOR OF PHILOSOPHY to the Tamil Nadu Agricultural University, Coimbatore is a record of *bona fide* research work carried out by Thiru C. M. PAPPIAH under my supervision and guidance and no part of this thesis has been submitted for the award of any other degree, diploma, fellowship or other similar titles or prizes and that the work has not been published in part or full in any scientific or popular journal or magazine.

COIMBATORE

Date: 12-2-1983



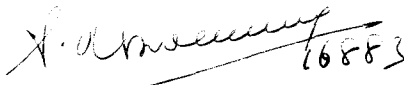
Dr. S. MUTHUSWAMI
CHAIRMAN

APPROVED On 16.8.83

ADVISORY COMMITTEE

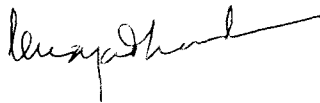
CHAIRMAN:

Dr. S. MUTHUSWAMI



MEMBERS :

Dr. V. N. MADHAVA RAO



Dr. G. V. KOTHANDARAMAN

Dr. J. B. M. MOHAMED ABDUL KHADER

EXTERNAL MEMBER:

ABSTRACT

ABSTRACT

STUDIES ON THE GROWTH AND DEVELOPMENT OF CHICORY

(Cichorium intybus L.)

BY : C. M. PAPPIAN
DEGREE : DOCTOR OF PHILOSOPHY IN
HORTICULTURE
CHAIRMAN : Dr. S. MUTHUSWAMI

Professor and Head,
Department of Pomology and Olericulture,
Faculty of Horticulture,
Tamil Nadu Agricultural University,
Coimbatore 641 003
1983

Studies were conducted (i) on the effect of time of sowing (ii) to determine the optimum stage for harvest and (iii) to produce viable seeds through GA application and vernalisation in chicory (Cichorium intybus L.). (The crop sown in October recorded the highest values for leaf number, leaf area, root weight, root length, root girth, girth/length ratio, fresh weight of tops, fresh weight of roots, dry weight of tops, dry matter production, harvest index, net assimilation rate, and relative growth rate.)

A negative relationship was noted between relative temperature disparity and photothermal unit on the one hand and root yield on the other. (Bolting was high in March, April and May sown crops while there was no bolting in crops sown in October, November and December.) Leaf and root nitrogen and potassium contents were high in October sown crop. Reducing sugar, non-reducing sugars, total sugars, glucose concentrations in the reducing sugars, bitter principles and chicory root infusion were also relatively high in the October sown crop. IAA oxidase and catalase activity was high in May and June sown crops and was less in October to December sown crops. Auxin and kinetin activities and their contents were high in October sown crops. Gibberellin and ABA like substances and their contents were high in April and May sown crops.

Leaf area, leaf number, fresh top weight, fresh root weight, dry top weight, dry root weight, HAR and RGR were high in tubers harvested 120 days after sowing. Root length was the greatest at 180th day and the highest mean weight of root was noted on the 150th day. The starch content was high on the 135th day. Reducing, non-reducing and total sugars, root protein, leaf and root amino-acids and root infusion were high on the 180th day after sowing. High IAA oxidase and catalase activity was noted on the 30th day.

The peroxidase activity was high on the 165th day. The auxin and kinetin contents were high on the 60th day whereas gibberellin content was high in the early stages and declined thereafter. The inhibitor content was high in the final stages of harvest.

(Seeds treated with GA at 500 ppm and vernalised for one day registered high percentage of germination, early flowering, greater plant height and high seed yield.)

ACKNOWLEDGEMENT

ACKNOWLEDGEMENT

I wish to record my deep debt of gratitude to Dr.S.Muthuswami, Professor and Head, Department of Pomology and Olericulture, Faculty of Horticulture, Tamil Nadu Agricultural University, Coimbatore for suggesting the problem and for his guidance, constructive criticism and help throughout the conduct of this study as well as in the preparation of this thesis.

I am extremely thankful to Dr.V.N.Madheva Rao, former Dean, Agricultural College and Research Institute, Coimbatore, Dr.G.V.Kothandaraman, Professor and Head, Department of Soil Science and Agricultural Chemistry, Dr.J.B.M.Md.Abdul Khadar, Professor and Head, Department of Spices and Plantation Crops for their guidance and advice as members of the Advisory Committee. I must also express my sincere thanks to Dr.K.G.Shanmugavelu, Professor and Head, Department of Horticulture, Agricultural College and Research Institute, Madurai, Prof.J.Sakaram Rao, formerly Professor of Crop Physiology, Dr.S.Sebalakrishnan, formerly Professor of Crop Physiology for their active interest in the execution of studies as former Advisory Committee Members.

/Contd../

CONTENTS

CHAPTER		PAGE NO
I	INTRODUCTION	1
II	REVIEW OF LITERATURE	5
III	MATERIALS AND METHODS	34
IV	EXPERIMENTAL RESULTS	57
V	DISCUSSION	171
VI	SUMMARY	203

LITERATURE CITED

LIST OF TABLES

TABLE NUMBER		PAGE NUMBER
1.	Weather data for the cropping period from 1.1.79 to 30.4.80.	36
2.	Weather data for the cropping period from 1.10.80 to 30.4.81.	39
3.	Weather data for the cropping period from 1.11.81 to 31.3.82.	40
4.	Effect of months of sowing on mean number of leaves.	58
5.	Effect of months of sowing on leaf area (dm ²)	59
6.	Effect of months of sowing on the percentage of bolted plants.	62
7.	Effect of months of sowing on mean root weight, length of the root, girth of the root and Girth/length ratio.	63
8.	Effect of months of sowing on fresh weight of tops, roots (kg/ha) and top/root ratio.	65
9.	Effect of months of sowing on dry matter production of tops, dry matter produc- tion of roots (kg/ha) and harvest index.	68
10.	Effect of months of sowing on Net Assimilation Rate.	70

/Contd../

TABLE NUMBER		PAGE NUMBER
11.	Effect of months of sowing on Relative Growth Rate.	72
12.	Relationship between months of sowing, Relative temperature disparity, photothermal unit and yield of chicory roots.	74
13.	Effect of months of sowing on nitrogen content in leaves and roots.	78
14.	Effect of months of sowing on the phosphorus content in the leaves and roots.	82
15.	Effect of months of sowing on percentage of potassium content in the leaves and roots.	84
16.	Effect of months of sowing on reducing sugar, non-reducing sugar and total sugars (per cent on dry weight basis).	86
17.	Effect of months of sowing on reducing sugar, glucose and fructose content in the roots (per cent on fresh weight basis).	89
18.	Effect of months of sowing on crude fibre content, bitter principles, starch content and specific gravity of infusion.	91
19.	Effect of months of sowing on the protein content in chicory leaves and roots.	94
20.	Effect of months of sowing on IAA oxidase, peroxidase and catalase activity in leaves and roots.	97

/Contd.../

TABLE NUMBER		PAGE NUMBER
21.	Wheat coleoptile bioassay for auxins in leaves and roots in different months of sowing (percentage of wheat coleoptile growth over control) .	101
22.	Effect of months of sowing on auxin content in roots and leaves (IAA equivalent /ug/g on fresh weight basis) .	104
23.	Rice leaf sheath bioassay for gibberellins, length of the second leaf sheath on seventh day (mm) .	106
24.	Effect of months of sowing on gibberellin content (ug/g) on fresh weight basis.	110
25.	Radish cotyledon bioassay for cytokinin weight of radish cotyledon (mg/cotyledon) .	112
26.	Effect of months of sowing on kinetin equivalent (ug/g) on fresh weight basis) .	115
27.	Cress seed bioassay for inhibitors germination percentage.	117
28.	Effect of months of sowing on ABA equivalent (ug/g) on fresh weight.	120
29.	The relationship between photo-thermal unit on various characters.	124
30.	Effect of stages of harvest on mean number of leaves, leaf area, length, girth of the root, girth/length ratio and mean weight of a root.	126

/Contd../

TABLE NUMBER		PAGE NUMBER
31.	Effect of stages of harvest on fresh weight of tops, roots and top/root ratio.	131
32.	Effect of stages of harvest on dry weight of tops, dry weight of roots and harvest index.	133
33.	Effect of stages of harvest on Net Assimilation Rate and Relative Growth Rate.	135
34.	Effect of stages of harvest on nitrogen, phosphorus and potassium content (per cent).	137
35.	Effect of stages of harvest on starch granules accumulation.	139
36.	Effect of stages of harvest on starch content, crude fibre content and bitter principles.	141
37.	Effect of stages of harvest on reducing, non-reducing and total sugars of chicory root (per cent on dry weight basis).	143
38.	Effect of stages of harvest in reducing sugar, glucose and fructose concentration in chicory root on fresh weight basis.	146
39.	Effect of stages of harvest on protein content and total amino-acid content.	148
40.	Aminoacids contents on 75th, 120th and 180th days of harvest.	150

|Contd..|

**TABLE
NUMBER**

**PAGE
NUMBER**

- | | | |
|-----|---|-----|
| 41. | Effect of stages of harvest on the specific gravity of the chicory root infusion. | 152 |
| 42. | Effect of stages of harvest on IAA oxidase, peroxidase and catalase activity. | 154 |
| 43. | Effect of stages of harvest on auxin content of leaves and roots (IAA equivalent (ug/g) and gibberellin content (ug/g) on fresh weight basis. | 156 |
| 44. | Effect of stages of harvest on kinetin equivalent and ABA like substances (ug/g) on fresh weight basis. | 159 |
| 45. | Association of yield with growth and other attributes. | 163 |
| 46. | Effect of GA ₃ and vernalisation of percentage germination, number of days for flowering, height of the plants, number of branches and mean seed yield of chicory. | 165 |
| 47. | Performance of seeds obtained from GA ₃ and vernalisation treatments on germination, bolted plants, fresh and dry weight of chicory roots. | 169 |

LIST OF FIGURES

FIGURE NUMBER		PAGE NO.
1.	Effect of months of sowing on mean weight of roots, length and girth of the root.	61
2.	Effect of months of sowing on fresh weight of roots and tops.	62
3.	Effect of months of sowing on RTD, PTU and fresh weight of the roots.	75
4.	Effect of months of sowing on nitrogen content in leaves and roots.	79
5.	Effect of months of sowing on reducing non-reducing and total sugars.	87
6.	Effect of months of sowing on starch, crude fibre and bitter principles.	92
7.	Effect of months of sowing on IAA oxidase, peroxidase and catalase activity in leaves.	98
8.	Effect of months of sowing on IAA oxidase, peroxidase and catalase activity in roots.	99
9.	Histograms showing wheat coleoptile bioassay for auxin in leaves and roots.	102
10.	Histograms showing rice leaf sheath bioassay for gibberellins in leaves and root.	107

Contd..

FIGURE NUMBER		PAGE NO
11.	Histograms showing radish cotyledon bioassay for cytokinin.	113
12.	Histograms showing cress seed bioassay for inhibitors.	118
13.	Effect of stages of harvest on leaf area, length and girth of the root, Length/girth ratio and mean weight of the root.	127
14.	Effect of stages of harvest on root girth and root weight	128
15.	Effect of stages of harvest on reducing sugar and non reducing sugar.	144
16.	Effect of stages of harvest on auxin and gibberellin content	157
17.	Effect of stages of harvest on kinetin equivalent and ABA like substances.	160
18.	Effect of GA ₃ and vernalisation on number of days for flowering, height of the plant, number of branches and seed yield.	166

INTRODUCTION

1. INTRODUCTION

Chicory (Cichorium intybus L.) belongs to Compositae family and is a native of Europe, naturalised in South America and familiar to many as a pot herb, a salad and a leading adulterant of coffee. It became popular in the late nintees and the early years of this century as a American farm crop (Bailey, 1942). It is grown in northern Europe for the beverage industry and for the production of chicons, a forced leafy head used as vegetable. In North America, chicory is used exclusively as a coffee extender or substitute. The major producers of chicory are the United Kingdom, Belgium, France, Netherlands, West Germany, Switzerland, South Africa and India (Narasingha Rao, 1960).

Chicory has been successfully cultivated in India as early as in 1919 at Coimbatore and in later years on the Nilgiris in Tamil Nadu and in Nadiad, Broach, Analsed and Jamnagar in Gujurat State, Munnar and Vettavada in Kerala, Karnataka, Himachal Pradesh and in Assam (Dinakaran and Sunderaraj, 1980). India produces annually about six to seven thousand tonnes of chicory powder. The cultivation of this crop is mainly concentrated on the hills and foot hills. The total area under cultivation in Tamil Nadu is 1100 hectares of which Coimbatore and Nilgiris districts account for nearly 90 per cent of the total area(Thulasidas and Chandramohan,196

Chicory production in India has to be increased to meet the demand both for internal consumption and for export, as it is being used as blending agent with coffee for the preparation of instant coffee, which finds great use within the country and is also exported. As chicory is considerably cheaper than coffee, its presence in coffee, if not disclosed, constitutes adulteration. On the other hand, many users prefer coffee blended with chicory. It therefore, depends on local circumstances whether chicory in coffee should be regarded as an improver or as an adulterant. Its presence in coffee significantly increases the proportion of coffee constituents entering into solution during infusion and appears to cause the aromatic constituents, mainly coffeol to be held in the brew.

The importance of this crop both for its medicinal value as well as a blending agent for coffee has been well recognised. Chicory contains the polyfructosan insulin as its storage carbohydrate having glucose and fructose as the structural unit (Singh and Bhatia, 1970). Upon hydrolysis, insulin yields substantial quantities of fructose and this was investigated as a possible fructose sugar crop (Bhatia, et al. 1974). With the increasing interest in fructose sugar in recent years, chicory could be reexamined for its potential source as a fructose crop.

Although this crop has good potentials, not much scientific work has been done particularly on the growth and development aspects. Some work on nutrition of chicory has been reported (Muthuswamy and Pappiah, 1980; Pappiah and Muthuswamy, 1981; Selvaraj, 1981). The ultimate expression of interactions between the environment and the inherent capacity of the crop involves the size and form of individual plants in the growth cycle and the pattern of the growth and development of the crop. The expressions are affected both through the quantitative processes such as cell division and cell elongation, photosynthesis, protein synthesis leading to increase of the total mass of the crop and qualitative processes such as morphogenetic changes like tuber initiation, leaf senescence leading to changes in the quality of growth. These processes are affected by changes in the total environment which consists of the immediate external aerial environment, the soil environment and the internal crop environment. For increasing production, techniques like optimum stage of harvest, role of environment in the production of quality tubers, the extent by which environment could be modified to increase the total output and to produce quality tubers are to be studied. Such an attempt will pave the way for increasing the production.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Plant performance depends on the optimal growth and development of the concerned crop as well as the functional attributes such as physiological and metabolic processes. According to Nishiuchi (1953), the tuberization in root crops is the result of a temperature gradient in the plant tissue in which the solute on being translocated from the warmer to the colder portions of the plant, accumulates in the latter regions inducing the formation and growth of the tuberous tissue. But high night temperatures prevalent in the tropics are not conducive to the highest productivity in tropical root crops while low night temperatures increased tuber weight in sweet potato (Kim, 1961). The growth and development of the root crops generally consist of three, more or less distinct though slightly overlapping phases. They are (i) an initial phase consisting of growth of the tops and absorbing roots only, (ii) an intermediate phase consisting of growth of the tops and absorbing roots simultaneously with initial development of the fleshy roots and (iii) a final phase consisting of a rapid development of the fleshy root (Edmond, 1971). Normally tuberization in root crops includes three separate processes, viz: (i) development of the tuber bearing roots, (ii) tuber initiation and (iii) tuber development to maturity (Enyi, 1973).

Tuberization is the term applied to the process of tuber formation. The term is also often used for the formation of root storage organs. A tuberous root is a thickened secondary root. A fleshy root is almost always an enlarged primary root as observed in the beet (Beta vulgaris L.) (Lowe and Wilson, 1974). In some tuber and root crops, bolting is a common phenomenon. Since seed quality is of the very greatest importance in determining not only yield but also the quality of the produce, the possibility of producing good quality seed locally by adopting suitable technique will eliminate the indiscriminate use of seeds from bolters (Saini and Singh, 1978). Information on growth and development of chicory roots with particular reference to ecophysiological factors affecting root tuber development, maturity as influenced by time (stage of harvest) as well as techniques for quality seed production is scanty. Attempts have been made in this review to present the available information on chicory on these aspects. But for a more meaningful analysis, this review also includes parallel crops in which similar situation exists as for example in sweet potato, sugar beet, etc.

2:1:1 Growth

Spaldon and Krusenko (1963) found that delayed sowing of chicory lowered root/total weight ratio, produced fine roots and had variable effect on root length. The

stand was reduced by delayed sowing but bolting was unaffected. Tusno and Fujise (1965) in sweet potato (*Ipomoea batatas* L.) and Loomis and Bennett (1966) in sugar beet (*Beta vulgaris* L.) showed that they continued to add new leaves to the canopy during tuberization and thus were able to maintain a reasonable leaf area throughout the season. According to Haynes et al. (1967) in yam (*Dioscorea alata* L.) the leaf area declined as tuberization began. (Loomis et al. (1969) were of the view that the nature of the foliage cover was an important factor in determining the efficiency with which the available solar radiation was used in primary production. The leaf area index in most root crops increased slowly after planting due in part to the use of relatively low plant densities. Depending upon species and environment, six to twelve weeks of growth may be needed to achieve full cover. Leaf area development may change with the onset of storage organ development.) Thiagarajan (1969) observed a positive correlation between leaf area and yield of tubers in *Coleus parviflorus* Benth.

Loomis and Williams (1969) in their review on productivity and morphology of crop stands observed that there were two general patterns of partitioning during the growth and development of plants with underground storage organs. In one type, characterised by sugarbeets, storage

organ growth began early in the seedling stage and continued throughout the vegetative period of the plant. There was an intermediate competition between shoot growth and storage organ growth. Shoot growth had a priority for assimilate supply even though the relative magnitude of top and root may change as root size increased. A balance between these two activities was maintained throughout the growing season. In the other type, early vegetative growth was characterised by shoot and fibrous root development. Storage organ growth began later, was usually more determinate in nature and often required an inductive environment. The switch to storage organ growth may be quite dramatic with a subsequent cessation and or even negative growth of the shoot tissues.

Enyi (1972) reported that in cassava there was continuous addition of leaves to the canopy during tuberisation, whereas Moorby and Milthorpe (1975) observed that leaf area declined as tuberization began in potato (Solanum tuberosum L.). The length of time before full cover was achieved after planting could be a major limitation to seasonal productivity. However, rapid growth of shoot in sweet potato was not related to high root tuber bulking rate. When the fast growth of tops decreased, the growth of the root tuber was favoured (Chatterjee and Mandal, 1976), but Pushkaran et al. (1976) obtained a negative relationship with leaf area and yield in potato. According to Sishachkar et al. (1982) the

tuberizing ability of sweet potato was positively correlated to initial leaf area and negatively to subsequent leaf growth. Beyond initial phase, tuberization became independent of lamina size. During tuber initiation, some roots were transformed into storage organs and when tuber started to fill the growth rate was strongly depressed.

2:1:2 Yield

As early as in 1934, Beattie, et al. (1934) observed that the time of planting in sweet potato had an important bearing on yield. He had further pointed out that there was consistant decrease in yield as the planting date was delayed. (Watson (1958) reviewed the contribution of leaf area and NAR to biological yield and stated that for obtaining high harvest index, economical yield should be higher than the biological yield and environment as well as the genetic make-up exerted influence on this aspect.)

(According to Orchard and Van Rooyen (1953) a more suitable climate was important than any other factor for chicory which required a mild, warm climate for four or five months, followed by summer for a period of three months for drying tubers.) The effect of sowing time on the yield and quality of chicory was also studied by Spaldon and Krasusko (1963) in Belgium. The highest root yield was obtained from the earliest sowing date in mid-April. One week's delay in sowing resulted in yield loss of 4.08%, two week's delay

in a loss of 10.79%, three week's delay in a loss of 30.67% and four weeks delay in a loss of 38.43%. Van Hossin and Andersen (1964) found that the earliest sowing time was the best for high yield. (Delay in sowing usually resulted in reduction in dry matter content of the roots but increased that of leaves.) Even with earlier sowing, the number of bolters was very small. Kaufmann (1965) also made similar observations and considered mid-May sowing was the best and yields were reduced by about 50% in late sowings.

In sweet potato Uexkull (1965) recorded a positive correlation between relative temperature disparity (RTD) and yield. Verma et al. (1969) reported that significantly higher tuber yield was obtained when the crop was planted in the first week of June and the yield of tubers decreased with delay in planting time at Kalyanpur. Planting in the first October was found to be conducive to obtain higher yield under Coimbatore condition in sweet potato (Sundararaj et al. 1969). (According to Sirohi and Surya-Narayana (1970) high dry matter in chicory was obtained in sowing on 30th September.) The best time of planting sweet potato was the first week of June in Uttar Pradesh (Singh, 1971). Planting in May-June was recommended for Assam (Tapan Dutta, 1971). Mandal and Singh (1971) recommended planting during June-October and October-January.

Shanmugavelu et al. (1972) found that planting the crop in the second fortnight of September and the first fortnight of October in that order was found to be conducive to obtain higher yield in sweet potato. Venugopal et al. (1973) related the sweet potato yield as a function of certain climatic parameters and found that the mean RTD values during the months of development showed positive correlation. Badillo-Peliciano and Lugo-Lopes (1976) found that tuber yields in sweet potato were the highest in crop planted in November and the lowest when planted in March or May.

(Sundararaj and Thulasidas (1976) reported that chicory was sensitive to environment and good crops could be obtained when planted in September and October in southern parts of this country. April-May planted crops began to flower early and tuber formation was affected. Wilson (1977) stated that the parameters such as crop Growth Rate (GCR) and Relative Growth Rate (RGR) which expressed the rate increases in dry matter and Net Assimilation Rate (NAR) which expressed the efficiency of leaf surface in accumulation of dry matter could be employed to evaluate the environmental influence on crop growth and development.) (Mandal (1978) studied the seasonal influence on the growth and yield of coleus and reported that planting in the first week of October recorded the highest yield followed by September and August under Kerala conditions.) (Planting during March

to June recorded luxuriant vegetative growth with less tuberization. Tuberization was inversely proportional to the vegetative growth and it reduced the tuber yield in summer months. (Sharma and Sirohi (1981) recommended October sowing for high yield in chicory.)

2.1.3 Temperature

Gregory (1956) postulated that diurnal temperature variation affected tuber development; leaf growth and high tuber production were favoured by low temperature and tuber yield was found to be decreased more by high night temperatures than by high day temperatures. Went (1957) was of the opinion that night temperatures was more important for its influence on the yield of root crops. Borah and Milthorpe (1967) found a temperature of 20°C as optimum for potato tuber formation and the number of tubers per plant was higher at low temperature. Low night temperatures increased tuber weight in sweet potato. Bodlaender (1963) studied the optimal average temperature for the growth and development of potato crop and found that the average may be in the order of 15-20°C. Potato tuber production also occurred in the tropical low lands with a temperature range of 22-30°C. (In general high temperature was favourable for stem growth and unfavourable for leaf expansion and tuber production.) The optimum temperature for leaf growth was reported to be 12-14°C, while that for maximum stem

weight was 18°C. Consequently the ratio of the weight of leaves to stems decreased with increasing temperature.) Tuber weights were higher at 12-14°C under low light intensity and winter conditions.

(Meijaard (1963) studied the quantum of temperature requirement for chicory and reported that optimum temperature was 26 to 28°C and the crop required a temperature sum of about 42 week degrees measuring the average temperature per week above 2.6 to 2.8°C. Khitryut (1975) found that the temperature range of 17-20°C was optimum for chicory root development. Sundararaj and Thulasidas (1976) noted that tuberization in chicory was most rapid in July at 19-20°C under Russian conditions. Dorrell and Chabey (1977) found that considerable reaction which caused the decline of fructose appeared to be independent of temperature effect. Goldwin (1982) studied the association between components of the weather and horticultural parameters and identified that temperature components could be correlated with the interpretation of root crop yields.

2.1.4 Quality

(Since temperature is a measure of disordered energy, lowered plant temperature will be associated with lowered molecular activity (Pacher, et al., 1948). The lowering of temperature may cause extensive changes in the amount and nature of substrates available in the plant. The increase in sugars and acids may help to account for the

effects of lowered temperature (Arreguin - Losano and Bonner, 1949). In sugarbeet, lower night temperature led to enhanced sugar content (Ulrich, 1952). Wassink (1953) studied the effect of temperature on the starch hydrolysis and found increased hydrolysis at temperature below 13°C. The hydrolysis at low temperature may be related to the greater acidity of the leaves or to the proportionate rates of starch synthesis and hydrolysis. The plant tissue showed marked increases in sugars at temperatures below 10°C.

(A lot of variations in the chicory grades at different seasons was noted by Orchard and Van Rooyen (1953) and particularly consistent differences were noted in the crude fibre content.) They established a direct inverse relationship between reducing sugar and crude fibre percentage. Shortening the growing season by late sowing reduced the number of roots suitable for processing (Van Hossin and Andersen, 1964). Simmonds (1964) mentioned that the important quality constituents of chicory were bitter extractives (4.0%), in the raw root and sugar (1.1%). (Madadeviah and Singh (1964) analysed the green tops of chicory and found that the protein preparation contained 30% protein, 20% mineral matter, 8% ether extractives, 40% carbohydrates and negligible quantity of crude fibre. Leaf protein extraction was optimum in 150 days old plants. Fiale and Jolivet (1960) studied the quantitative variation of carbohydrates among

the different growth periods in witloof chicory. Water soluble carbohydrate contents were higher than ethanol soluble carbohydrates at the end of September and the beginning of October. They decreased during the growth period, whereas ethanol soluble carbohydrate contents increased.) Khan et al. (1980) estimated the carbohydrate and protein content of gladiolus corms and found that the main carbohydrates were in the form of starch and this was associated with appreciable quantity of protein. The time of planting did not influence these contents. Doney et al. (1981) reported that increased root yields in sugarbeet were generally accompanied by decrease in sucrose percentage due to high temperature.

2:1:5 Nutrients

Leonard et al. (1949) found that as the sweet potato plant was approaching maturity, the nitrogen content of leaf blades declined. The potassium content should be at least 2% throughout the entire season. The percentage of potassium decreased during the period of growth of the fleshy roots. The highest values were found at the time of inception of fleshy root formation.

Pankov (1976) established a close curvilinear relationship between leaf nitrogen content and root yields of carrot. For high root production, 3.2 per cent of leaf

nitrogen was required. In nitrogen deficient medium, leaf nitrogen content declined and the contents of phosphorus and potassium rose resulting in increased dry matter and sugar content. He also found a close relationship between carrot yield and leaf phosphorous and phosphorus deficiency reduced the yield. In carrots, good plant growth and high yields were obtained only from plants with more than 1.7% potassium content. Potassium deficiency decreased leaf potassium contents and increased phosphorus content. A close correlation was obtained between leaf potassium concentration and plant productivity.

According to Sharma et al. (1978) a pronounced decrease in sweet potato dry matter content was associated with increase in potassium level. Nitrogen content in the leaves was higher than in tubers.

Delegher et al. (1980) studied the N, P and K content in the leaves and roots of chicory. The quantity of N and K contents diminished in the root and increased in the leaves as the plant aged.

2.1.6 Enzyme activity

(The enzyme IAA oxidase, catalase and peroxidase were detected in reasonable amounts in the chicory leaves and roots (Anon, 1950).) Galston and Dalberg (1954) reported that chicory root cap cells were high in IAA oxidase while cells of the meristem showed low activity and its increase

paralleled increase in cell size. Peroxidase activity showed a progressive decrease. Janson (1955) noted high peroxidase activity in the formation of lignin in carrot tissue. Tanaka and Langerah (1976) found that peroxidase and polyphenol oxidase activities increased with the increase in chicory plant age. In carrot, large variations were detected in the specific activities of peroxidase and catalase at different months of sowing. No correlation was found between peroxidase activity and catalase activity and between protein and carrot weight.

2:1:7 Endogenous hormonal changes

Extensive work has been conducted on the occurrence and distribution of growth substances and growth inhibitors. However, relatively little work has been done on the possible significance of growth regulating substances on the actual process of tuber formation. Davis (1941) found that auxin may accelerate the formation of tubers and promote their growth, but it had no specific tuber inducing effect. Morel and Wetmore (1951) were able to obtain growth of tissues from the tubers of Amorphophallus rivieri L. in media containing auxin and coconut milk. Nitsch and Nitsch (1956) found that Helianthus tuberosus L. required only auxin whereas Chapman (1958) showed that tuber tissue grows only in the presence of auxin and coconut milk. Vardjan and

Nitsch (1961) reported that apical part of the chicory showed the greatest kinin content and the basal most part (root) showed the greatest auxin content. They found a gradient of cytokinin activity in the root with the maximum at the base near the root stem transition region. Zeatin ribboside was isolated from the roots.

Since Torrey's (1965) review on the root hormones and plant growth, considerable progress has been made in developing an understanding of the hormonal control of vascular cambium activation in roots and the factors influencing the formation of the secondary vascular tissues of the roots. These processes are of considerable importance commercially in the production of root crops such as carrot, radish, turnip etc. Radin and Loomis (1971) extracted and characterised the effect of cytokinin in radish roots and identified them as zeatin and its riboside and ribotide. These cytokinins when applied to the cultured radish roots, induced secondary thickening. They believed that the shoot provides the cytokinin to the root to induce secondary thickening which proceeds ontogenetically from root base to the tip. Thickened radish roots produced another unidentified cytokinin which they suggested may be the form exported to the shoot. They further postulated that as auxin was always essential to cambial initiation and continued activity, it was possible that auxin flow towards root tip

accounted for the acropetal progression of cambial initiation. Wareing and Phillips (1978) observed high auxin content at the basal and high cytokinin content at the apical end of chicory root. Melansan and Trewavas (1982) outlined a possible model of auxin activity which involved sequential and progressive changes in the synthesis of nuclear proteins and the control of gene expression eventually leading to DNA synthesis.

2:2 Stages of harvest

As the active principle of chicory (Cichorium intybus L.) is localized in the roots, it is essential to know changes occurring in root growth and development at different stages for the optimum period of harvesting.

2:2:1 Growth

According to Orchard and Van Rooyen (1953) the chicory root took five to six months for maturity under South African conditions, but in colder areas, this period may be as long as eight months. The crop was generally ready for lifting in four to four and a half months after germination of seeds. In spite of repeated removal of seed heads with delayed harvest, the quality of the root was very poor, being fibrous and excessively forked. A delay in harvest by a month led to marked decrease in quality in spite of an increase in the weight of roots (Narasimha Rao, 1960).

Ivins and Bermer (1966) noted that chicory being a root crop, behaved like sugarbeet (Beta vulgaris L.) in the growth pattern of foliage and root. The root length and girth increased rapidly upto the 180th day and thereafter gradually upto the 195th day. The mean weight of the root increased substantially on the 150th day and attained the maximum on the 180th day and thereafter declined. The weight of tops attained the maximum weight on the 180th day and declined thereafter.

Chaurasia et al. (1971) reported that by the 180th day, the crop attained the maximum growth and the root had fully matured. According to them leaf yield increased with an increase in root yield upto the 180th day and then decreased. The ratio of the leaf weight to the root weight was high at the early stages and then declined gradually. Bolting started after the plants had matured (180th day) under Punjab conditions. Bolting changed the structure of the roots, which became pithy, fibrous and hollow. This type of root was not preferred for coffee blending. (Mani et al. (1975) found that the foliage yield in coleus was high on the 105th day after sowing and thereafter a declining trend was noticed.) (Vasanthakumar and Chacko (1980) observed a continual increase in number of leaves and root growth from the first to the final harvest in the medicinal yam.) A high leaf number on the 90th day

after sowing, significant differences in tuber girth on the 90th and 120th day, increasing tuber length upto the 120th day, increase in tuber girth/length ratio with the advancement of the growth stage and high percentage of bolted plants on the 120th day have been observed in recent studies in chicory (Selvaraj, 1981). Vijayakumar (1982) reported that in coleus the leaf number, leaf area, length of the root and fresh weight of the plant increased upto the 100th day and the length and girth of the tuber were high on the 150th day after planting.

2.2.2 Yield

According to Orchard and Van Rooyen (1953) there will not be any increase in weight of the chicory root once maturity was reached and a month's delay in harvest led to decrease in quality. Harvesting of chicory roots on the 150th day registered high yield (Thulesidas and Chandramohan, 1964). The yield of chicory roots also increased significantly in later harvests and the highest yield occurred after 195 days (Chaurasia *et al.*, 1977). He also stated that the percentage of chicory dry matter continued to increase with an increase in the harvesting period and the root dry matter was more than that of leaf dry matter and was less when harvested after 120 days. Mani *et al.* (1975) found that coleus tuber yield was high when tubers were harvested on the 120th day after planting. According to Scott and

Bouwkamp (1975), the dry matter of sweet potato increased till final harvest but foliage attained the highest value on the 120th day after planting and declined thereafter.

In Jerusalem artichoke (Helianthus tuberosus L.) yield was high in the last harvest (Dorrel and Chubey, 1977) and in chicory also, delayed harvesting increased root yield (Chubey and Dorrel, 1978). Sampathkumar (1979) reported that the dry matter of sweet potato tubers and foliage increased till the final harvest and the same results were obtained in sugarbeet (Bogchi and Chanda, 1980 and Rajmohan and Sethumadhavan, 1980) observed in coleus a slow rate of dry matter accumulation upto the third week after tuber initiation, after which there was a deep increase. Vijayakumar (1982) reported that there was steady increase in the fresh weight of coleus tuber till harvest which attained the highest value on the 120th day. He also stated that the dry matter production of coleus foliage increased upto the 100th day and thereafter decreased, while in tuber, its content increased upto harvest.

2.2.3: Nutrients

On analysis the chicory root was found to contain 1.87% nitrogen extract, 0.61% fibre and 0.83% of protein (Anon, 1950). Sampathkumar (1979) reported that the total nitrogen content of sweet potato leaves increased upto 105 days and phosphorus and potassium content increased till

135 days. Selvaraj (1981) found that the nitrogen content of chicory leaves increased from the 30th to the 60th day and then decreased gradually as the growth advanced. The nitrogen content in the root also followed the same trend but was lower than the leaves. The phosphorus content in the leaves varied from 0.075 to 0.115 per cent 30 days after sowing to 120 days after sowing. The root phosphorus content was high on the 90th day. The potassium content in the root was more in the leaves at each stage. In coleus, Vijayakumar (1982) reported that nitrogen in the foliage reached a peak on the 100th day, phosphorus and potassium on the 120th day and the 40th day after planting respectively.

2:2:4 Quality

Anderson (1937) stated that the total sugar content in sweet potato increased from 1.6 per cent at the time of first harvest to 4.6 per cent at subsequent harvest. The starch content in the tubers gradually increased during the growing season. The starch content ranged from 19 to 32 per cent. Its content increased upto the final stage. Caravaggi and Manfredi (1937) observed that the bitter principle was due to glycoside of the fructose in chicory roots. The chicory roots contained 4% of bitter principles and 2.18% of protein (Anon, 1950). Orchard and Van Rooyen (1951) identified the bitter principle in chicory as consisting mainly of lactucopicrin. They considered that the percentage

of crude fibre, sugars and protein would form a reliable index reflecting the quality of root. According to them, the determination of reducing sugar would give good comparative values of sugar present in different stages of root. The protein content in the chicory leaves and roots was found to vary among the stages of harvest. The differences in the specific gravities of coffee and chicory extract formed one of methods of detecting chicory quality. The specific gravity of the coffee infusion was 1.0080 and for chicory it varied from 1.0090 to 1.0236 depending upon the stages of maturity and types of processing (Narasingha Rao, 1960).

Rutherford and Flood (1971) reported that invertase activity increased during chicory tuber maturation and then declined. This presumably was the reason for the low sucrose content in delayed harvest. They also noted that hydrolase activity increased during tuberization and continued several weeks thereafter. The fructose level seldom dropped below normal during final harvest. The reducing sugar concentration increased with maturation and then either stabilised or declined. Edmond (1971) found that in chicory the soluble sugars were high during early stages but later declined. The total sugars decreased but starch content was high in tuberous roots as they advanced in age and increased in thickness. Chaurasia et al. (1971) stated that harvesting of chicory roots beyond the 180 day changed the structure of roots, which became pithy, fibrous and hollow.

Bhatia et al. (1974) reported that the maturity of the chicory root was characterised by an increase in the content of glucofructosans at the expense of sucrose. They also reported that bound fructose increased and bound glucose decreased with the advancement in the growth of the roots. Significant interactions between harvesting and other variables such as reducing sugar, fructose, glucose have been obtained (Chubey and Dorrel, 1974). They also found that both reducing sugar concentration and quality changed with tuber maturation. The fructose concentration in reducing sugars declined steadily from 82.4% in tubers harvested in September to 71.8% in tubers harvested in November. In colous Mani et al. (1975) found that there was no variation in protein per cent among stages of harvest.

Plinik and Vervelde (1976) found that the fructose concentration declined from 18.7 to 16.4% in chicory tubers harvested from September to February in Netherlands. According to Sundararaj and Thulasidas (1976) the protein content in the chicory root was 20.31% on fresh weight basis. Dorrel and Chubey (1977) reported that the fructose concentration and the corresponding increase in glucose were associated with later stages of maturation. Chubey and Dorrell (1978) found that harvesting at 125 days after sowing of chicory increased total reducing sugars and glucose concentrations but decreased fructose concentrations. They

also stated that because total reducing sugar content increased significantly with later harvests, it appeared that harvesting should be delayed until mid-October to permit maximum root development and total reducing sugar accumulation. Sampathkumar (1979) observed that in sweet potato an upward trend upto 105 days in the protein content which declined thereafter. The total sugars and non-reducing sugars increased upto the 60th day and the greatest reducing sugar content was found at 90 days after planting. Bagchi and Chanda (1980) found that the extractable protein in sugarbeet was the highest when harvested at 90 days.

Suzuki and Cutcliffe (1981) reported that rutabagas (Brassia napobrassica Mill) harvested in October and November contained high level of sugars which were more than 51% of dry matter. Roots harvested in September contained less sugar than those harvested later.

2.2.5 Amino acids

Diamair (1940) reported that in chicory glutamic acid stimulated the reaction, suggesting that glycine is formed by transamination. Glycine, serine, alanine arose independently but were closely related compounds. Evidence has been presented that glycolic acid was the precursor of glycine. Serine was formed from hydroxy pyruvic acid and alanine from pyruvic acid. The flavour of the roasted chicory was due to histidine bases resulting from the

decomposition of proteins. Weelsch (1952) stated that in addition to their primary role as structural units of proteins, aminoacids and their amides served various other functions: as agent for storage and translocation of nitrogen, as an intermediate in biosynthesis and as an important components of co-enzymes. Sakmi (1955) reported that glycine and serine were directly interconvertible and were important in the synthesis of other amino acids. Loomis and Stumpf (1958) pointed out that glutamic acid occupied an unique position as a mediator between nitrogen metabolism and carbon metabolism. According to them, most of all the amino nitrogen of plants was channelled through glutamic acid by action of glutamic dehydrogenase and numerous transaminases. Bouniols (1974) reported an increase of free proline and free arginine as the age of chicory root growth enhanced.

2.2.6 Endogenous hormonal changes

According to Lawrence and Baker's (1963) hormones do not serve as quantitative control agents over the degree of tuberization; instead, they may act as switches to initiate events and subsequent variations in the cambial activity which may be determined by other factors. Palmer and Smith (1970) initiated tuberization in isolated potato stolons through an application of cytokinin. Extensive starch accumulation was the first event in the initiation

process, an event that was inhibited by gibberellins. Gibberellin was also found to inhibit tuberization (Railton and Wareing, 1973). Similar results have been reported in Dahlia (Brian et al. 1974) where abscisic acid promoted tuberization but gibberellin inhibited it. According to Halevy and Brian (1975), it was conjectural whether storage roots and tubers released growth inhibitors which served in the mobilization of resources from the rest of the plant. Forsline and Langille (1975) found that inductive conditions caused a very marked increase in cytokinin activity in potato shoots after two inductive cycles; the active cytokinin reached maximum values in below ground tissues after six days and tubers were initiated after 8-10 days. It may be that transport of cytokinin took place from shoot to root. Loomis and Rappaport (1976) reported that the early growth period was dominated by shoot and fibrous root growth, but it was without competition from storage organs and may have an extended duration. Storage organ growth was initiated later in the life cycles, frequently in response to environmental and hormonal influences.

2.3 Effect of gibberellic acid and vernalization on chicory seed yield

According to Keller et al. (1962) the over all effect of vernalisation was to increase growth potential of the embryo, by utilizing sucrose in endosperm for root

growth. Leopold (1964) observed that environmental cues might provoke the induction of the reproductive state in leaves, the initiation of floral meristems and the morphological development of flowers. The triggering of these reproductive development was usually done by environmental variables such as light, temperature etc. (Whyte, 1968). According to Zeevaart (1968) the physiological control of flowering may be exerted at any of several fairly definite phases. Flowering may be regulated by the termination of the juvenile phase of development. Environmental cues served principally to synchronise the timing of the flowering events (Wareing and Phillips, 1978). Thomas (1981) stated that low temperature commonly increased earliness in flowering, high seed yield and good quality seed.

2.3.1 Effect of vernalization

According to Curtis and Chan (1930), celery required vernalization for flowering; as a result, active leaf growth occurred during the first year of culture and exposure to chilling at 4 to 10°C for a week, caused flowering within the same year of culture. When chicory seeds were vernalised at 5°C and sown, the leaves were hairy and more serrated. They stood erect rather than spread out and produced flowers (Hartman, 1956). In turnip, shooting and flowering were accelerated by seed vernalisation and rutabagas required vernalisation before flower initiation

(Highkin, 1956). According to Rappaport and Wittwer (1956) seed vernalization accelerated flowering in seed lettuce and produced seed stalk without proceeding to head formation. Chouard (1960) reported that sugarbeet required an absolute vernalization and it yielded flowers in the very year of sowing. He also stated that vernalization could be achieved in very young plants and even in seeds but responsiveness increased with duration. Wareing and Villers (1961) found that the low temperature response was apparently due to production of growth stimulation. In the lettuce seed, there may be a thermolabile complex macromolecular compound, which was sufficiently modified by low temperature to permit initiation of germination. Rappaport and Wittwer (1965) stated that early flowering of broad leaved chicory was favoured by cold exposure. The plants from vernalised seeds developed the same morphological characteristics of the over-wintered plants and flowered earlier while non-vernalised plants produced vegetative head and exhibited no evidence of bolting. Gregory (1965) stated that the carrot seeds were chilled at 2°C for 50 to 80 days and one third of the plants flowered in the same year. Seget and Phulik (1967) expressed the opinion that duration of vernalisation needed to enter into generative phase was reduced when chicory seeds were vernalised.

Brocklehurst and Dearman (1980) reported that the difference in the composition of the dry seed appeared to be responsible for the observed difference in the speed of germination of the carrot seeds harvested in different dates. Valette (1981) found that the speed and uniformity of germination were accomplished in the Witloof chicory seeds vernalised at 10° and 15°C and good performance at low temperature was associated with good field emergence, growth and crop quality.

2.3.2 Effect of Gibberellin

Harington and Rapoport (1957) stated that one of the consistent effects of gibberellin was the acceleration of flowering. According to Lang (1957) GA is a flower promoter though its stimulation of stem growth was perhaps due to its mobilization action associated with growth. According to Chailakhyan (1958) GA is critically involved in the initiation of flowering in some species, especially those requiring cold treatment. Bukovac and Wittwer (1957) reported that gibberellin promoted flowering in head lettuce. The effects of gibberellin were additive to those of long days, high temperature and seed vernalisation. Gibberellin treated plants produced no heads and produced stems prior to the appearance of visible primordia. Wittwer (1958) found that the gibberellin treatment of chicory seed had no effect on germination of the resulting seed or growth of the

subsequent crop. An enhancement of flower primordia formation in the late varieties of red clover by gibberellin treatment was observed by Stoddart (1959). Harada and Nitsch (1959) were able to induce flowering in non-vernalized cold requiring chrysanthemum by means of gibberellin treatment. Lang and Reinhard (1961) found that chicory recorded earlier flowering by application of gibberellins. They also found that an extensive array of cold requiring species was brought to flowering by gibberellin applications, including the biennial Hypocyanus, cruciferous species (cabbage, beet, turnip, etc.,) and other cold requiring species (carrot, chicory, endive, parsley, etc.).

Koller et al. (1962) found that GA was active in breaking seed dormancy induced by high temperature or coumarin. The effect of GA applied together with low temperature was additive. Leopold (1964) explained the ability of gibberellins to cause elongation in rosette plants in a manner suggestive of bolting and this led to investigations of the possibility that gibberellins could cause flowering in rosette plants. According to Michniewicz and Kamiensk (1964) gibberellin treated chicory plants flowered without cold treatment while none of the control plants flowered. Gibberellin induced bolting and flowering without chilling in carrot (Gregory, 1965). Wittwer and Buckovac (1957) have also reviewed the effect of gibberellin in inducing flowering in cold requiring species.

MATERIALS AND METHODS

MATERIALS AND METHODS

3. MATERIALS AND METHODS

Studies on the growth and development of chicory were carried out during January 1979 to March 1982 in the department of Spices and Plantation Crops, Faculty of Horticulture, Tamil Nadu Agricultural University, Coimbatore, under irrigated conditions.

3:1 Materials

3:1:1 Location

The experiment was conducted at the University Orchard, Coimbatore situated in the western region of Tamil Nadu at 11° north latitude and 77° east longitude at an altitude of 426.72 m above mean sea level. The mean annual rainfall of the University orchard is 644 mm.

3:1:2 Field

Field experiments were conducted in Field No.7 and 9 of the tank bed area of the University Orchard, Faculty of Horticulture, Tamil Nadu Agricultural University, Coimbatore.

3:1:3 Soil

The soil of the experimental field is clay loam in texture and well-drained. The chemical characteristics of the soil are as follows :

Available nitrogen (kg/ha)	: 92.42
Available phosphorus (kg/ha)	: 14.47

Available potassium (kg/ha)	:	480.32
E.C. (mmhos/cm)	:	0.2
pH (1.2 water suspension)	:	8.1

3:1:4 Weather and climate

The average rainfall in this tract is 644 mm distributed over 41.5 rainy days. The mean maximum and minimum temperature are 33.1 and 21.4°C respectively. Data on various weather parameters during January 1979 to December, 79, November, 80 to April, 81 and November, 81 to March, 82 which formed the cropping periods are furnished in Tables 1, 2 and 3 (Kulandavelu et al. 1980; Kulandavelu, 1981 and Anon, 1982).

3:1:5 Season

To find out the optimum time for sowing, seeds were sown on the third week of every month during January 1979 to December, 79. Among these months of sowing, October was selected as the best one on the basis of results of the previous experiment, and for further studies such as on stages of harvest and seed production, the sowing was done in October, 1980.

3:1:6 Crop and variety

The imported cultivar, viz., TLD from Belgium was employed for all the experiments. This variety is suitable for the production of roots, having a duration of 120 days yielding 5 to 7 tonnes of dried chicory roots (Michael Sivets and Normalw Destosier, 1979).

Table 1 WEATHER DATA FOR THE CROPPING PERIOD

1.1.79 to 30.4.80

Std week	Month	Dates	<u>Temperature</u>		<u>Relative</u>		Rain fall	Evapo ration	Sun- shine hrs.
			Max	Min	humidity(%)	0722 0422			
					hrs	hrs			
1.	January	21-7	29.1	17.7	95	42	-	4.4	9.9
2.		8-14	29.3	17.3	91	46	-	4.4	8.1
3.		15-21	30.1	18.8	91	47	-	4.7	8.7
4.		22-28	30.4	19.2	87	47	-	5.3	9.2
5.		29-4	32.3	17.8	88	41	-	5.2	9.6
6.	February	5-11	32.2	18.1	87	40	1.6	5.7	9.4
7.		12-18	30.5	20.7	88	56	35.8	5.0	6.0
8.		19-25	30.2	21.3	96	60	50.1	3.1	6.2
9.		26-4	30.1	20.2	88	57	34.4	4.7	7.9
10.	March	5-11	33.4	20.9	93	45	16.9	5.0	7.9
11.		12-18	34.9	19.5	90	32	0.8	5.6	10.7
12.		19-26	34.9	20.5	89	37	-	6.8	10.9
13.		26-1	35.9	21.0	80	31	-	7.5	10.5
14.	April	2-8	36.7	21.0	79	26	-	7.6	10.4
15.		9-15	36.8	21.6	82	31	-	7.7	10.4
16.		16-22	34.9	22.5	86	42	37.8	6.5	7.6
17.		23-29	35.7	22.5	85	38	1.4	7.0	10.3
18.		30-6	35.8	23.7	84	44	4.4	7.1	8.1
19.	May	7-13	33.9	23.3	79	52	24.4	7.2	6.7
20.		14-20	34.7	21.4	73	40	Tr	8.3	10.6
21.		21-27	35.7	22.8	80	40	-	8.3	8.8
22.		28-3	35.4	23.0	84	45	Tr	7.5	9.3

Std week	Month	Dates	Temperature		Relative humidity(%)		Rain fall	Evapo- ration	Sun shine
			Max	Min	0722 hrs	0422 hrs			
23.	June	4-10	34.6	22.9	85	48	33.1	7.3	9.0
24.		11-17	33.0	23.5	81	59	14.3	6.7	4.8
25.		18-24	30.3	22.7	76	67	19.6	8.1	2.0
26.		25-1	29.9	22.9	70	61	27.6	8.1	5.3
27.	July	2-8	29.8	22.3	78	64	13.9	5.3	1.7
28.		9-15	30.3	22.1	82	62	16.1	6.6	2.6
29.		18-22	32.3	18.9	91	48	-	6.6	6.2
30.		23-29	30.8	22.8	84	65	3.8	6.0	2.4
31.		30-5	29.9	22.8	79	62	7.9	6.8	3.9
32.	August	6-12	29.5	22.2	77	59	19.7	7.3	5.5
33.		13-19	33.6	21.1	81	49	-	9.2	7.8
34.		20-26	32.1	21.5	90	49	0.8	6.8	5.4
35.		27-2	32.2	21.7	91	49	1.8	5.6	4.1
36.	September	3-9	32.2	22.0	89	56	4.3	5.2	5.1
37.		10-16	32.1	21.1	92	57	28.6	5.1	5.5
38.		17-23	28.9	21.9	93	72	68.4	3.8	4.0
39.		24-30	30.7	22.1	81	54	-	7.2	5.7
40.	October	1-7	32.5	20.9	88	50	19.8	7.3	8.8
41.		8-14	30.9	22.3	94	59	46.2	4.3	6.7
42.		15-21	31.2	20.5	87	43	3.4	5.4	10.2
43.		22-28	29.1	21.3	93	70	88.3	4.0	4.1
44.		29-4	29.6	21.0	95	60	56.4	3.7	6.4

Std week No.	Month	Dates	Temperature		Relative humidity(%)		Rain fall mm.	Evapo- ration	Sun shine hrs.
			Max	Min	0722 hrs	0422 hrs			
45.	November	5-11	27.7	21.3	94	75	21.7	2.0	3.0
46.		12-18	27.3	21.2	96	84	283.2	1.3	2.7
47.		19-25	27.4	21.1	94	75	293.6	2.1	2.7
48.		26-2	28.3	21.6	94	65	15.2	3.0	6.0
49.	December	3-9	28.2	20.5	93	61	0.7	3.3	6.7
50.		10-16	28.2	20.8	91	60	3.7	3.6	5.2
51.		17-23	29.5	19.1	91	45	-	4.5	8.9
52.		24-31	28.5	17.2	90	29	0.4	4.5	8.7
1.	January 1980	1-7	29.4	16.6	85	43	-	5.0	10.3
2.		8-14	29.0	15.7	89	37	-	5.3	10.7
3.		15-21	29.1	17.4	85	38	-	5.6	10.0
4.		22-28	30.0	14.7	85	30	-	6.1	10.8
5.	February	29-4	30.8	17.1	81	31	-	6.5	8.9
6.		4-11	31.5	17.8	85	31	-	6.6	9.6
7.		12-18	32.0	16.8	85	29	-	6.4	10.0
8.		19-28	33.3	16.5	81	31	-	8.0	11.2
9.	March	29-4	34.7	16.3	85	32	-	7.3	10.6
10.		5-11	34.9	19.5	84	32	5.9	6.9	9.0
11.		12-18	32.3	19.9	86	36	19.0	6.1	9.8
12.		19-25	34.9	17.2	75	21	-	5.2	11.1
13.	April	26-1	34.4	21.9	78	37	-	6.7	9.2
14.		2-8	34.3	23.6	77	41	3.3	7.3	7.0
15.		9-15	35.7	23.1	84	40	-	7.4	10.4
16.		16-22	34.8	23.3	76	47	16.9	7.3	7.7
17.		23-29	34.8	22.3	88	48	69.9	5.9	7.2

Table 2 WEATHER DATA FOR THE CROPPING PERIOD
(1.11.80 to 30.4.81)

Std week No.	Month	Dates	Temperature		Relative humidity(%)		Rain fall mm	Evapo- ration	Sun shine hrs.
			Max	Min	0722 hrs	0422 hrs			
44.	November	29-4	31.1	19.1	85	38	-	5.0	4.7
45.	1980	5-11	30.6	19.2	90	52	46.3	3.2	4.4
46.		12-18	28.0	21.9	95	75	125.9	3.5	5.2
47.		19-25	28.7	20.4	91	56	3.7	3.2	4.4
48.	December	26-2	29.1	18.5	87	53	0.8	4.0	4.7
49.		3-9	29.9	19.6	88	52	5.6	4.2	3.7
50.		10-16	30.5	19.6	89	45	-	4.4	4.6
51.		17-23	29.3	18.4	86	55	-	3.4	6.1
52.		24-31	29.3	18.4	89	47	-	3.6	5.6
1.	Jan.1981	1-7	30.1	18.3	83	42	-	4.8	4.9
2.		8-14	30.8	17.3	89	41	-	4.9	4.5
3.		15-21	28.8	19.5	83	50	0.2	4.2	5.1
4.		22-28	30.6	18.4	88	47	-	4.8	5.3
5.	February	29-4	31.7	15.6	86	35	-	5.5	5.3
6.		5-11	32.0	18.9	85	38	-	5.8	5.9
7.		12-18	32.1	18.5	77	36	-	6.1	6.0
8.		19-25	32.3	15.4	73	21	-	6.8	6.3
9.	March	26-4	35.0	16.0	68	17	-	7.2	5.9
10.		5-11	33.9	20.1	80	29	-	7.4	7.6
11.		12-18	33.5	21.0	83	29	19.6	6.2	6.3
12.		19-25	34.8	22.4	84	39	1.8	6.3	5.1
13.	April	26-1	34.8	22.0	80	39	-	6.7	5.4
14.		2-8	35.5	22.4	89	40	17.6	6.8	4.8
15.		9-15	35.8	22.5	83	37	-	7.3	5.8
16.		16-22	36.2	22.9	81	41	9.5	7.8	6.8
17.		23-29	35.8	23.2	75	34	-	7.8	7.0

Table 3 WEATHER DATA FOR THE CROPPING PERIOD
(1.11.81 to 31.3.82)

Std week No.	Month	Dates	<u>Temperature</u>		<u>Relative humidity(%)</u>		Rain fall mm	Evapo- pora- tion	Sun shine hrs.
			Max	Min	0722 hrs	0422 Hrs			
44.	November 1981	29-4	29.7	20.5	91	73	60.9	3.6	4.6
45.		5-11	30.0	20.6	93	74	33.8	3.4	3.8
46.		12-18	39.9	20.4	90	56	-	3.6	4.3
47.		19-25	30.2	17.5	88	43	-	3.9	3.1
48.	December	26-2	28.1	19.5	90	67	40.0	2.8	4.7
49.		3-9	28.8	17.2	92	58	13.4	3.1	3.5
50.		10-16	29.0	15.2	94	58	0.2	4.5	4.2
51.		17-23	27.0	19.6	93	74	14.2	2.7	7.7
52.		24-31	29.5	16.0	93	50	-	4.2	4.9
1.	January 1982	1-7	28.2	17.0	93	49	-	3.8	9.1
2.		8-14	28.8	17.8	89	48	-	4.0	9.0
3.		15-21	30.0	16.2	92	42	-	4.4	10.9
4.		22-28	29.3	17.3	91	42	-	4.7	9.0
5.		29-4	30.1	16.7	89	41	-	4.8	9.5
6.	February	5-11	31.9	19.4	82	32	-	5.3	10.2
7.		12-18	33.3	15.3	79	27	-	6.4	11.0
8.		19-25	33.6	17.6	85	26	-	6.5	11.0
9.		26-4	34.2	17.9	79	25	-	7.0	11.0
10.	March	5-11	35.2	20.5	82	33	-	6.8	10.7
11.		12-18	35.0	19.3	85	29	-	7.3	10.7
12.		19-25	35.2	20.0	80	28	15.5	7.3	10.1
13.		26-1	34.6	20.9	87	30	2.8	6.0	10.7

3:2 METHODS

Studies on the ecophysiological factors influencing tuberization

In order to assess the optimum time for raising the chicory crop and also to produce better quality tubers, trials on monthly sowing were carried out from January, 1979 to December, 1979.

3:2:1:1 Preparation of the land

The land was ploughed thoroughly with tractor-drawn mould board plough followed by harrowing. The field was properly levelled. A basal dose of farm yard manure containing 0.5% of nitrogen, 0.4% of phosphorus and 0.5% of potassium was applied at the rate of 20 tonnes per hectare. Ridges and furrows were formed 30 cm apart.

3:2:1:2 Experimental details

The experiment was laid out with twelve treatments under simple randomised block design, replicated three times.

3:2:1:3 Treatments

Sowing was done monthly in 10 sq.m. plots on the sides of the ridges in a thin line. Seeds were covered with fine sand upto 2 to 3 cm thickness over the seeds and irrigated. Plants were thinned 30 days later, leaving one seedling per hole for every 20 cm in the row. (A basal

application of 80 kg of nitrogen, 100 kg of phosphorus and 125 kg of potassium per hectare was given at the time of sowing. After thinning, 80 kg of nitrogen per hectare were applied as top dressing (Muthuswami and Peppiah, 1980). Irrigation was given once in three days till thinning. Thereafter, weekly irrigations were given. First weeding was given at the time of thinning. Later, second and third weedings were given on the 30th day and 60th day after sowing respectively. Harvesting was done 120 days after sowing for all the months of sowing. Tubers were cleaned free of soil and the net plot yield was recorded. The twelve months of sowing constituted the 12 treatments.

3:2:1:4 Growth observations

The following characters were studied at monthly intervals. The observations were made on ten plants in each treatment per replication at random.

3:2:1:5 Number of leaves and leaf dimensions

The total number of leaves including the dried leaves was recorded at monthly intervals. The length and width of the leaf at the highest point were measured in ten leaves and expressed in centimeters.

3:2:1:6 Leaf area

The leaf area was calculated at monthly intervals (for each date of sowing) from 30 days after sowing till harvest. The calculation was done according to the formula

$LA = (L \times W \times N) K$ where L = maximum length of the leaf, W = maximum width of the leaf, N = Number of leaves and K = factor 0.728 (Milthorpe, 1967) and was expressed as dm^2 .

3:2:1:7 Bolting

The number of bolted plants per plot was recorded on 80, 90, 100, 110 and 120th days after sowing and was expressed as percentage.

3:2:1:8 Mean tuber weight

The weight of ten roots was weighed and mean was calculated and expressed as grams per root.

3:2:1:9 Tuber length

The length of the tuber was measured from the tip of the tuber to the top of the crown and expressed in cm.

3:2:1:10 Tuber girth

The girth of the tuber was measured at the maximum bulked point and expressed in cm.

3:2:1:11 girth/length ratio

The girth/length ratio was calculated from the individual measurements from length and girth.

3:2:2 Yield

3:2:2:1 Fresh weight of tops

The fresh weight of tops including shoot, main axis, petioles and leaves were recorded for each treatment at the harvest stage (120 days after sowing) and expressed as kg/ha.

3:2:2:2 Fresh weight of roots

The fresh weight of roots was recorded after cleaning the roots and expressed as kg/ha.

3:2:2:3 Top/root ratio

The top/root ratio was calculated from the individual measurements of fresh weight of tops and fresh weight of roots.

3:2:2:4 Dry matter production of tops

Dry matter was estimated by using the method of Humphries (1956). Individual plants were harvested from each monthly sown plot and the tubers and tops were separated. The tops were then dried in the open for 48 hours. Then they were kept in hot air oven at 90°C for 48 hours until consistent weights were obtained and expressed in kg/ha.

3:2:2:5 Dry matter production of roots

The dry matter production of roots was recorded as above and expressed as kg/ha.

3:2:2:6 Harvest index

The harvest index was calculated by adopting the formula of Watson (1972) as follows :

$$\text{Harvest index} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

3.2.2.7 Relative Growth Rate (RGR)

Periodical sampling was done and dry weight of the plants was recorded at 30 days intervals. The RGR was calculated with the following formula.

$$RGR = \frac{\log e W_2 - \log e W_1}{T_2 - T_1}$$

wherein W_1 = Dry weight of the plant at T_1 time

W_2 = Dry weight of the plant at T_2 time

(Wallace et al. 1972)

3.2.2.8 Net Assimilation Rate (NAR)

Sampling was done at 30 days intervals and dry weight of the sample was recorded. The leaf area was worked out for a particular interval. From this NAR was calculated as per procedure of Wallace et al. (1972)

$$NAR = \frac{W_2 - W_1}{T_2 - T_1} \times \frac{\log e L_2 - \log e L_1}{L_2 - L_1}$$

wherein W_1 = Weight of the sample at T_1 time

W_2 = Weight of the sample at T_2 time

L_1 = Leaf area of the plant at T_1 time

L_2 = Leaf area of the plant at T_2 time

3.2.2.9 Relative Temperature Disparity (RTD)

To have an understanding on the effects of temperature on yield, an attempt was made to calculate the relative temperature disparity as proposed by Uexkull (1965)

and was worked for the cropping period by using the following formula

$$RTD = \frac{\text{Average temperature disparity}}{\text{Average maximum temperature}} \times 100$$

where, average temperature disparity = Mean maximum (day) temperature (-) mean minimum (night) temperature. The resulted RTD values were correlated with the fresh weight of the roots. The cropping duration was the interval between date of sowing and date of harvest.

3:2:2:10 Photo Thermal Unit (PTU)

In order to relate the difference in yield in the different months of sowing, photo thermal unit was worked out. This was calculated by the summation of deviation of daily temperature from 25°C and was multiplied by day length hours (Bodlaender, (1963); Landsberg and cutting, 1977). PTU values were correlated with other attributes. This was worked out for the cropping duration from date of sowing to date of harvest.

3:2:3 Chemical analysis

3:2:3:1 Collection of plant samples

The third leaf from the top and middle portion of the roots were collected (Chapman, 1958). Samples so collected were dried at 70°C in hot air oven powdered and used for the estimation of total nitrogen, phosphorus, potassium, crude fibre content, bitter principles, starch content, reducing sugar and non reducing sugar. For hormonal

3:2:4:3 Starch content

The starch content was estimated as per the method suggested by McCready et al. (1950). The glucose content was determined from the standard curve and multiplied by 0.9 to determine the starch content. This was expressed as percentage on dry weight basis.

3:2:4:4 Estimation of total sugars, reducing sugars and non-reducing sugars

These were estimated by method described by Lane and Edynon (1923).

3:2:4:5 Estimation of carbohydrates fraction

The water soluble carbohydrates were quantitatively extracted from both ethanol preserved and dehydrated roots with boiling water and extracts so obtained, were clarified. The clear extract was used for the estimation of glucose and fructose following the method of Bhatia et al. (1974).

3:2:5 Estimation of enzymes

3:2:5:1 IAA oxidase activity

The colorimetric method of Parthasarathy et al. (1970) was adopted to estimate the IAA oxidase activity.

3:2:5:2 Estimation of peroxidases

The peroxidase activity of fresh sample was estimated as per the method described by Parur (1962).

3:2:5:3 Estimation of catalase

The volumetric method of Dekock et al (1960) was followed to estimate the catalase activity of fresh samples.

3:2:6:1 Estimation of protein

Protein content was estimated as per method described by Lowry et al. (1951).

3:2:6:2 Quality of chicory infusion

Five gram sample from chicory roasted tubers were taken in a mortar and ground into a fine powder. This was placed in the percolator for the extraction of infusion for 30 minutes. The specific gravity was estimated for the infusion. The specific gravity for the coffee infusion was also estimated for comparison (Simmonds, 1964).

3:2:6:3 Two dimensional chromatography and spectrophotometric estimation of amino-acids

Aminoacids in the alcohol soluble fractions of plant materials were separated, identified and quantitatively estimated by following the procedure outlined by Block (1958).

3:2:7 Bioassay of hormones

A known weight of samples was extracted with 80 per cent methanol for 24 hours at 5°C and re-extracted

twice and bulked. Methanol peroxide free was diluted with glass distilled water. The extract was filtered and purified as detailed below for estimation of different hormones as per procedure described by Murakami, 1970; Abdel Rahman et al. 1973.

3:2:7:1 Wheat coleoptile bioassay for auxin

The method described by Mitchell and Livingston (1968) was followed.

3:2:7:2 Rice second leaf sheath bioassay for gibberellin

The rice second leaf sheath bioassay described by Murkani (1970) was adopted.

3:2:7:2 Radish cotyledon bioassay for cytokinin

The radish cotyledon bioassay as described by Letham (1968) was used for estimating cytokinins.

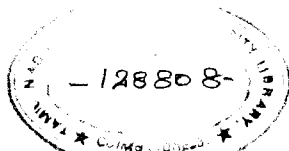
3:2:7:4 Cress seed germination bioassay for inhibitors

The cress seed (Lepidium sativum L.var. Curled) germination bioassay test as described by Masuda (1962) was adopted for estimation of inhibitors.

3:2:8 Estimation of hormones

3:2:8:1 Auxins

The quantity of auxins was worked out from individual Rf position which showed significantly more response than



control by referring to the standard curve obtained from the bioassay of authentic IAA. Then the individual values were pooled together and presented as IAA equivalent ($\mu\text{g/g}$) fresh weight of plant samples.

3:2:8:2 Gibberellins

The total quantity of gibberellin like substances was estimated in the same manner by referring to the GA_3 bioassay standard curve and expressed as GA_3 equivalent ($\mu\text{g/g}$) on fresh weight basis.

3:2:8:3 Cytokinins

The total quantity of cytokinin like substances was estimated by referring to the kinetin bioassay standard curve and expressed as Kinetin equivalent ($\mu\text{g/g}$) on fresh weight of the sample.

3:2:8:4 Inhibitors

The inhibitor content was worked out for the R_f of 0.8 referring to the ABA bioassay standard curve and expressed as ABA equivalent ($\mu\text{g/g}$) on fresh weight of the sample.

3:3 STUDIES ON THE STAGE OF HARVEST

In order to assess the optimum stage of harvest, a field trial was laid out. The sowing was done in October 1980 (in the month when the highest yield was obtained in the previous experiment). Chicory seeds of the variety TLD was used in this experiment also. The crop was raised as described

in the previous experiment. At fifteen days interval from the 30th day after sowing plants were harvested and all the growth attributes were recorded. Harvest on the 30th, 45th, 60th, 75th, 90th, 105th, 120th, 135th, 150th, 165th and 180th days after sowing formed the different stages for harvest. Totally there were eleven treatments. The experiment was conducted in a randomised block design with three replications.

3:3:1 Growth

The data on number of leaves, leaf area, tuber length, tuber girth, tuber girth/length ratio and mean weight of tuber were recorded as in the previous experiment.

3:3:2 Yield

The fresh weight of tops, fresh weight of tuberous roots, top/root ratio, dry weight of tops, dry weight of roots, harvest index were recorded for all stages of harvest. Net assimilation rate and relative growth rate were worked out for all stages of harvest as in the previous experiment.

3:3:3 Nutrients

The nitrogen, phosphorus, and potassium content in the leaves and roots were analysed as in the previous experiment.

3:3:4 Starch granules accumulation

In order to find out the actual stage of starch accumulation, the middle portion of the chicory roots at each stage of harvest was fixed in FAA and dehydrated in different

concentration of ethyl alcohol and fixed in paraffin wax. Sections were taken as per the procedure of Sass (1964). The sections were viewed at 20 x and starch granules were counted with the help of stage micrometer. The mean number of granules per field was worked out.

3:3:5 Quality

The percentage of starch, crude fibre, bitter principles, reducing sugars, non-reducing sugars, total sugars, glucose and fructose concentrations in the reducing sugars protein content, total amino acids, aminoacid fractions, specific gravity of the infusions were analysed as in the previous experiment.

3:3:6 Enzyme activity

The enzyme activity was analysed as in the previous experiment.

3:3:7 Endogenous hormonal changes

The endogenous hormones were bioassayed for the samples obtained from the stages of harvest. The procedure adopted was the same as in the previous experiment.

3:4:1 Effect of GA₃ and vernalisation on the chicory seed production

In order to obtain good quality seeds which can produce non-bolted plants, the following treatments were imposed on the seeds of chicory TLD variety obtained from Belgium during October, 1980.

- T1 GA₃ 250 ppm + vernalisation for 30 days
- T2 GA₃ 500 ppm + vernalisation for 30 days
- T3 GA₃ 250 ppm + vernalisation for 10 days
- T4 GA₃ 500 ppm + vernalisation for 10 days
- T5 GA₃ 250 ppm + vernalisation for one day
- T6 GA₃ 500 ppm + vernalisation for one day
- T7 Seeds soaked in water + vernalisation for one day
- T8 Control (no treatment)

Fifty grams of seeds per treatment were taken in a petridish. GA₃ solutions were prepared and the seeds were soaked in 25 ml of the solution and placed in refrigerator for 30 days, 10 days and for one day. Treated seeds were sown and the crop was raised as described in the previous experiment. The experiment was replicated four times in randomised block design. The plot size was 10 m². The other cultural operations such as irrigation, weeding, etc., were done uniformly to all treatments. The following morphological characters were recorded and mean values were worked out.

3.4.1:1 Germination percentage of the seeds

Germination count was made on the 20th day after sowing and the percentage of germination was worked out for each treatment.

3:4:1:2 Number of days for flowering

The mean number of days taken for flowering from sowing was worked out and mean values were recorded.

3:4:1:3 Height of the plant

The height of the main axis was measured in centimeters from the basal most leaf to the tip of the plant on the 120th day.

3:4:1:4 Number of branches

The mean number of branches per plant was counted on the 120th day.

3:4:1:5 Seed yield per plant

The seed yield per plant was recorded and expressed in grams.

3:4:2 Performance of seeds obtained from the previous treatment

A fresh sowing was done with seeds obtained from previously treated seeds during October, 1981. Seeds were sown on the sides of the ridges formed 30 cm apart and irrigated. The experiment was laid out in the plots of 10 m² for each treatment and replicated four times in randomised block design. The other details of cultivation were similar to previous experiments. The chicory roots were harvested 120 days after sowing. The following data were recorded.

3:4:2:1 Germination per cent

Germination count was made on the 20th day after sowing and the percentage of germination was worked out for each treatment.

3:4:2:2 Percentage of bolted plants

The bolted plants per treatment was counted and the percentage of bolted plants was calculated for each treatment and replication.

3:4:2:3 Fresh weight of chicory roots

The fresh weight of chicory roots per plot was recorded and per hectare yield was calculated for each treatment.

3:4:2:4 Dry weight of chicory roots

The dry weight of chicory roots per plot was recorded and per hectare yield was worked out for each treatment.

3:4:2:5 Percentage of dry matter production

The percentage of dry matter production was calculated from dry weight of the roots and fresh weight of the roots.

3:5 STATISTICAL ANALYSIS

The data collected from various experiments were subjected to statistical analysis as per Panse and Sukhatme (1957). Simple correlations were worked between photothermal unit and other parameters and between stages of harvest and other parameters as per procedure of Snedecor and Cochran (1967).

EXPERIMENTAL RESULTS

4. EXPERIMENTAL RESULTS

The results of the analyses and observations recorded during the course of the experiment are presented in this chapter.

4:1 Months of sowing

4:1:1 Growth attributes

4:1:1:1 Number of leaves

The number of leaves produced at 120 days was high in August sowing (38.3), followed by July and January sowing (35.3). The mean number of leaves produced in April and May sowings was very low (25.3 and 21.6 respectively). Production of leaves during October to December was also relatively higher. In general, the increase in the production of leaves from the 30th day to 60th day and from 60th to 90th day was markedly high. Thereafter only a slight increase was noted. At all the stages the differences in values among the different months were significant (Table 4).

4:1:2 Leaf area

The highest leaf area was recorded in August sowing at the first two stages but at the 60th and 90th days, July sowing and January sowings recorded significantly the highest leaf areas. The increase in leaf area from

Table 4 EFFECT OF MONTHS OF SOWING ON MEAN
NUMBER OF LEAVES

S.No.	Month of sowing	(Days after sowing)			
		30	60	90	120
1.	January	3.2	19.2	34.8	35.3
2.	February	2.9	16.9	28.9	31.6
3.	March	2.7	15.8	27.0	29.0
4.	April	1.9	9.6	14.9	15.3
5.	May	1.5	8.4	10.6	11.0
6.	June	2.6	17.2	29.3	31.0
7.	July	3.4	20.3	34.9	35.3
8.	August	3.9	22.6	37.3	38.3
9.	September	2.6	17.2	29.6	31.0
10.	October	2.5	17.1	29.3	30.6
11.	November	2.9	21.6	32.3	33.6
12.	December	2.9	22.8	33.7	34.3
	S.E.	0.224	1.148	1.178	1.17
	CD (P=0.05)	0.674	3.446	3.534	3.51

Table 5 EFFECT OF MONTHS OF SOWING ON LEAF AREA (dm²)

S.No.	Month of sowing	(Days after sowing)			
		30	60	90	120
1.	January	0.81	26.83	47.93	50.45
2.	February	0.62	33.89	40.09	44.75
3.	March	0.04	16.92	32.87	40.02
4.	April	0.02	17.64	29.70	33.52
5.	May	0.40	11.68	24.97	28.62
6.	June	0.60	25.47	42.78	44.11
7.	July	0.41	29.53	42.62	44.04
8.	August	0.93	24.14	46.18	51.62
9.	September	0.22	18.27	40.01	41.12
10.	October	0.78	28.10	40.60	44.32
11.	November	0.63	18.34	43.72	48.64
12.	December	0.31	15.63	44.39	49.69
	S.E.		1.860	2.145	
		NS			NS
	CD (P=0.05)		5.580	6.436	

the 30th to 60th day was of a higher magnitude in all the months of sowing (Table 5). The increase from the 60th to the 90th day was also relatively greater and thereafter only a slight increase was recorded.

4:1:1:3 Percentage of bolted plants

Bolting was observed very early (80th day after sowing) in March, April and May sowings and on the 90th day after sowing in crops sown in January and February also. At 100th day after sowing, bolting was noted in the crops sown from January to July. On 110th and 120th day, bolting was noted in all the months of sowing from January to August and December. No bolting was recorded in September, October and November sowings (Table 6). The highest bolting was recorded in March sowing (49.0%) followed by April sowing (48.2%).

4:1:1:4 Mean root weight

The crop sown in October recorded significantly the highest tuber weight (106.52 g) followed by September (102.85 g) and August sowings (101.65 g). The tuber weight was the least in April, May sowings (54.50 and 54.40 g) Table 7; Fig.1).

4:1:1:5 Length of the roots

The mean values for root length harvested from crops sown in different months differed significantly. The roots of September sowing registered the highest

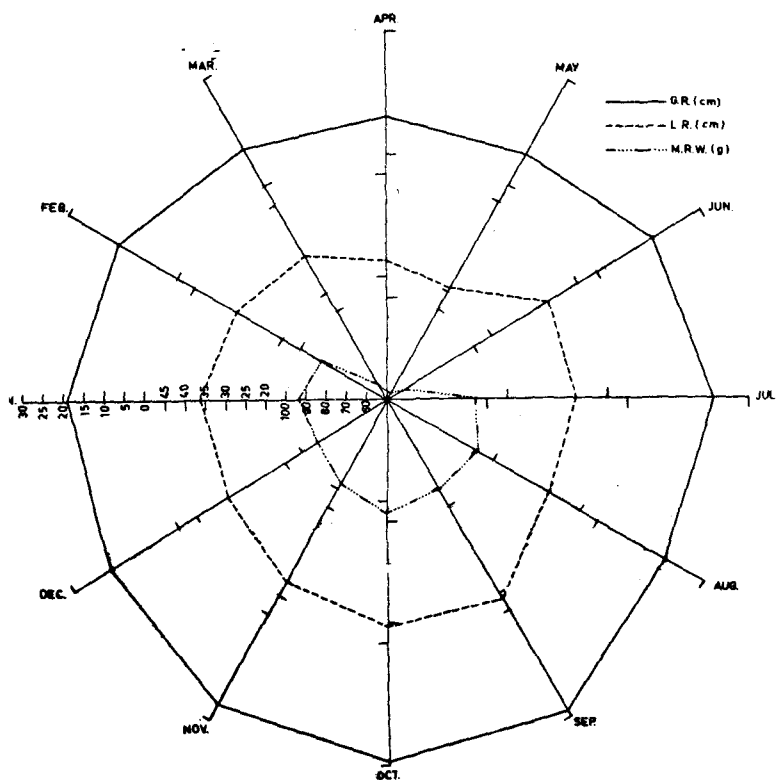
Table 6 EFFECT OF MONTHS OF SOWING ON THE
PERCENTAGE OF BOLTED PLANTS

S.No.	Months of sowing	Days after sowing				
		80	90	100	110	120
1.	January	-	2.7	4.8	4.9	10.0
2.	February	-	6.8	9.3	11.5	26.3
3.	March	8.0	12.0	24.0	42.0	49.0
4.	April	11.0	22.0	32.0	36.0	48.2
5.	May	7.6	9.3	9.8	13.9	21.3
6.	June	-	-	5.5	6.25	11.5
7.	July	-	-	3.0	4.75	10.25
8.	August	-	-	-	4.5	8.25
9.	September	-	-	-	-	-
10.	October	-	-	-	-	-
11.	November	-	-	-	-	-
12.	December	-	-	-	4.0	4.7
	Total	26.6	52.8	88.4	123.8	189.8
	Mean	8.86	10.56	12.624	12.475	21.06

Table 7 EFFECT OF MONTHS OF SOWING ON MEAN ROOT WEIGHT,
LENGTH OF THE ROOT, GIRTH OF THE ROOT AND GIRTH/
LENGTH RATIO

S.No.	Months of sowing	Mean Root Weight (g)	Length of the root (cm)	Girth of the root (cm)	Girth/length ratio
1.	January	93.26	36.0	19.0	0.531
2.	February	88.31	33.0	16.0	0.484
3.	March	58.58	30.4	10.5	0.355
4.	April	54.50	24.0	9.3	0.381
5.	May	54.40	21.0	9.2	0.438
6.	June	60.23	36.7	17.1	0.466
7.	July	95.09	37.8	21.5	0.578
8.	August	101.65	36.5	19.6	0.546
9.	September	102.85	47.1	29.0	0.625
10.	October	106.52	46.1	29.2	0.633
11.	November	98.74	41.3	25.4	0.615
12.	December	91.97	36.9	20.1	0.544
	S.E.	2.138	0.795	0.386	
	CD (P=0.05)	6.116	2.385	1.158	

FIG.1 EFFECT OF MONTHS OF SOWING ON MEAN WEIGHT OF ROOTS,
LENGTH AND GIRTH OF THE ROOT



length (47.1 cm), followed by October sowing (46.1 cm). The least root length was noted in crop sown in May (21.0 cm). The root length in crops sown in the other months registered intermediate values (Table 7; Fig.1).

4:1:1:6 Girth of the root

The root girth was significantly the highest in October sowing (29.2 cm), followed by September sowing (29.0 cm). The girth of the roots in March, April, May sowings was much less (10.5, 9.3, 9.2 cm respectively) which was about one third of October sowing (Table 7; Fig.1).

4:1:1:7 Girth/length ratio

The girth/length ratio was the highest in October sowing (0.633), followed by September sowing (0.625) and November sowing (0.615). The lowest girth/length ratio was recorded during March and April sowings (0.355 and 0.38 respectively (Table 7; Fig. 1)).

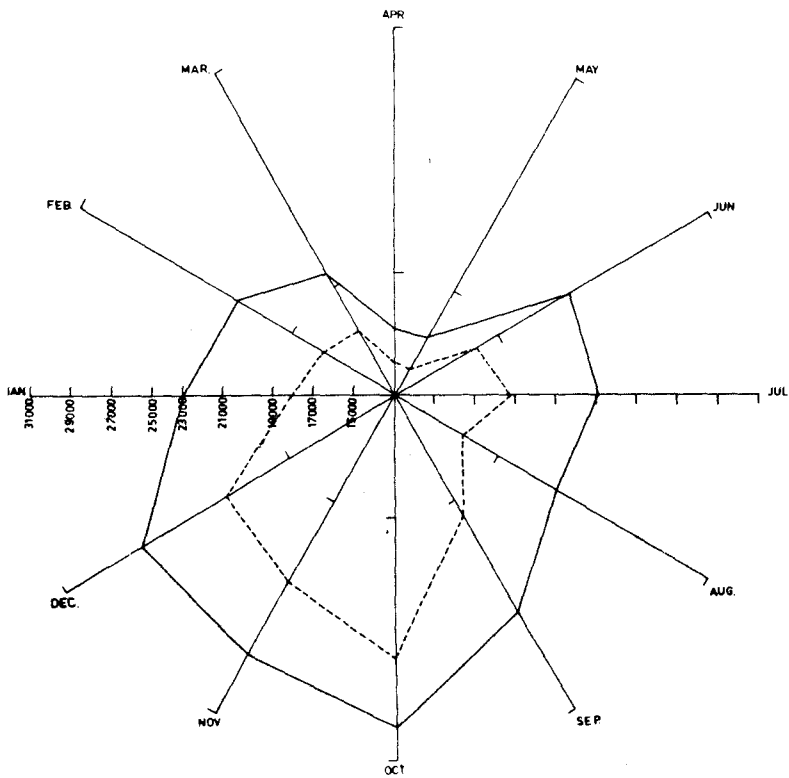
4:1:1:8 Fresh weight of the tops

Sowing during October recorded significantly the highest fresh weight (29,349 kg/ha) of the tops (including stems, leaves and petioles above the collar regions of the root) which was followed by November sowing (27,815 kg/ha) and December sowing (27,549 kg/ha). The lowest fresh top weight was noted in April and May sowings (16,308 and 16,348 kg/ha respectively (Table 8; Fig.2)).

Table 8 EFFECT OF MONTHS OF SOWING ON FRESH WEIGHT OF
TOPS, ROOTS (kg/ha) AND TOP/ ROOT RATIO

S.No.	Months of sowing	Fresh weight of tops (kg/ha)	Fresh weight of roots(kg/ha)	Top/ root ratio
1.	January	23470	18073	1.298
2.	February	22078	17123	1.289
3.	March	19764	16583	1.192
4.	April	16308	14633	1.144
5.	May	16348	14516	1.146
6.	June	23179	17818	1.293
7.	July	23171	18803	1.232
8.	August	22333	17060	1.309
9.	September	25422	19935	1.275
10.	October	29349	25976	1.129
11.	November	27875	23613	1.136
12.	December	27549	22773	1.209
	S.E.	670.44	631.06	-
	CD (P=0.05)	2011.34	1893.20	-

FIG 2 EFFECT OF MONTHS OF SOWING ON FRESH WEIGHT OF ROOTS AND TOPS



4:1:1:9 Fresh weight of the roots

Significant differences were noted among the crops sown in different months for this character also (Table 5; Fig.2). The highest fresh weight of the roots was recorded in October sowing (25,976 kg/ha), followed by 23,613 kg/ha in November sowing and 22,779 kg/ha in the December sowing. April (14,633 kg/ha) and May (14,516 kg/ha) sowings recorded only a little more than half the value of October sowing. Crops sown in September, July, January and June recorded intermediate values.

4:1:1:10 Top/root ratio

A high top/root ratio of 1,309 was noted in August sowing, followed by January (1,298) and June (1,293) sowings. Top/root ratio was low in October (1,129) and November sowings (1,136). The ratios were intermediate in the other months (Table 8).

4:1:1:11 Dry matter production of tops

The highest dry matter production of tops was recorded in October sowing (9,782.6 kg/ha), followed by November (8,991.9 kg/ha) and December sowings (8,609 kg/ha). The lowest values were noted in the April and May sowings (4,796.4, 4,793.2 kg/ha respectively) which were nearly half that of the value in October sowing (Table 9). The effect of time of sowing on dry matter production of tops was significant.

Table 9 EFFECT OF MONTHS OF SOWING ON DRY MATTER
PRODUCTION OF TOPS, DRY MATTER PRODUCTION
OF ROOTS (Kg/ha) AND HARVEST INDEX

S.No.	Months of sowing	Dry matter production of tops (Kg/ha)	Dry matter production of roots (kg/ha)	Harvest index (%)
1.	January	7570.9	5830.6	43.5
2.	February	6899.4	5350.9	43.7
3.	March	6176.2	5025.1	44.9
4.	April	4796.4	3875.8	44.6
5.	May	4793.2	3669.4	43.6
6.	June	7443.4	5780.6	44.3
7.	July	7234.2	6065.4	44.6
8.	August	7204.1	5331.2	43.5
9.	September	8200.6	6874.1	45.6
10.	October	9782.6	8679.3	46.9
11.	November	8991.9	7380.0	45.1
12.	December	8609.0	7116.5	44.4
	S.E.	231.2	157.19	0.271
	CD (P=0.05)	693.6	471.58	0.814

4:1:1:12 Dry matter production of roots

In this case also, significant differences were noticed in the crops sown during the different months. The dry matter in roots was the highest in October sowing (8,679.3 kg/ha). In November sowing the value was 7,380.0 kg/ha and in December sowing 7,116.5 kg/ha. Very low value were recorded in April and May sowings (3,875.8 and 3,669 kg/ha respectively). The dry matter production of roots in crops sown in the other months was not substantial (Table 9).

4:1:1:13 Harvest index

The harvest index ranged from 43.5 to 46.9 per cent and the highest value (46.9%) was noted in October sowing, followed by September, November and December sowings (45.6%, 45.1% and 44.4%). The least values were recorded in January and August sowings (43.3%). The time of sowing significantly affected the parameter also (Table 9).

4:1:1:14 Net assimilation rate (NAR)

The net assimilation rate progressively increased from 30th day of sowing and attained the maximum at 120 days after sowing. The increase was, however, of a greater magnitude from 60 to 90 days and was relatively less from 90th day to 120th day of sowing. At the stage of 30 days after sowing NAR showed only minimal values and among the

Table 10 EFFECT OF MONTHS OF SOWING ON NET ASSIMILATION
RATE (NAR)

S.No.	Months of sowing	Net assimilation rate mg/dm ² /day during stages (days after sowing)			
		30th	60th	90th	120th
1.	January	0.102	0.739	1.031	1.256
2.	February	0.109	0.764	1.073	1.274
3.	March	0.103	0.783	1.042	1.173
4.	April	0.107	0.632	0.943	0.948
5.	May	0.106	0.693	0.932	0.952
6.	June	0.109	0.749	1.034	1.279
7.	July	0.113	0.782	1.134	1.314
8.	August	0.116	0.794	1.231	1.432
9.	September	0.193	0.805	1.343	1.343
10.	October	0.201	0.932	1.643	1.743
11.	November	0.199	0.864	1.432	1.436
12.	December	0.194	0.853	1.339	1.339
	S.E.	NS	0.021	0.173	NS
	CD (P=0.05)		0.067	0.521	-

different months it was relatively high during October sowing ($201 \text{ mg/dm}^2/\text{day}$) which was followed by November sowing ($0.199 \text{ mg/dm}^2/\text{day}$). The least value was recorded in March sowing ($0.103 \text{ mg/dm}^2/\text{day}$) which was about half that of October sowing. However, the differences were not significant. At the second growth phase (30th to 60th day), the NAR showed an increase and was maximum during October sowing ($0.932 \text{ mg/dm}^2/\text{day}$), followed by November sowing ($0.864 \text{ mg/dm}^2/\text{day}$). But the influence was greater than 30th day and was significantly high. During the third phase (60 to 90 days) NAR was greater than the first two phases and followed the same trend by recording high NAR during October sowing with $1.643 \text{ mg/dm}^2/\text{day}$ followed by November sowing with $1.432 \text{ mg/dm}^2/\text{day}$. Here also low NAR was obtained in April sowing. During the fourth phase (90th to 120th days) the increase from the third phase was only very little. Here also the same trend was noted with high NAR during October sowing ($1.743 \text{ mg/dm}^2/\text{day}$) and November sowing ($1.436 \text{ mg/dm}^2/\text{day}$). The influence due to months of sowing was not significant at the last phase (Table 10).

4.1.1.15 Relative Growth Rate (RGR)

The RGR progressively increased irrespective of the month of sowing from 30th day to 120th day of sowing; however the quantum of RGR differed in different months of sowing. At 30 days after sowing, the crop sown in

Table 11 EFFECT OF MONTHS OF SOWING ON RELATIVE
GROWTH RATE (RGR)

S.No.	Months of sowing	Relative growth rate mg/g/day during stages (days after sowing)			
		30th	60th	90th	120th
1.	January	0.051	0.126	0.193	0.194
2.	February	0.048	0.123	0.190	0.198
3.	March	0.043	0.121	0.140	0.153
4.	April	0.041	0.114	0.143	0.142
5.	May	0.044	0.113	0.152	0.154
6.	June	0.049	0.092	0.154	0.158
7.	July	0.053	0.099	0.159	0.155
8.	August	0.054	0.144	0.162	0.160
9.	September	0.055	0.123	0.168	0.164
10.	October	0.062	0.143	0.207	0.209
11.	November	0.059	0.140	0.201	0.208
12.	December	0.054	0.120	0.194	0.199
	S.E.	NS	0.021	0.019	NS
	CD (P=0.05)		0.063	0.037	

October recorded high RGR (0.062 mg/g/day), followed by November sowing (0.059 mg/g/day) while a low RGR was recorded in April sowing (0.041 mg/g/day). During this phases, RGR was not significantly influenced by the time of sowing. In the second phase (30th to 60th day), the RGR was higher than the previous phase and was the highest in October sowing (0.143 mg/g/day), followed by November sowing (0.140 mg/g/day) while the lowest RGR was obtained in June sowing (0.092 mg/g/day). The third phase also followed the same trend by registering high RGR in October sowing (0.207 mg/g/day), followed by November sowing (0.201 mg/g/day). The least RGR was recorded in March sowing (0.140 mg/g/day) and the differences were highly significant. Only a little increase in the RGR was observed on the 120th day compared to previous phase and the highest values was again noted in October sowing (0.209 mg/g/day). RGR was the least in April sowing with 0.142 mg/g/day followed by March sowing (0.153 mg/g/day). These values however, did not differ significantly among the different months of sowing (Table 11).

4:1:1:16 Relative temperature disparity (RTD)

In order to assess the growth and development during different months of sowing relative temperature disparity (RTD) was worked out for the entire crop duration in respect of crops raised under each monthly sowing (Table 12; Fig.3).

Table 12 RELATIONSHIP BETWEEN MONTHS OF SOWING,RELATIVE
TEMPERATURE DISPARITY, PHOTOTHERMAL UNIT AND
YIELD OF CHICORY ROOTS

S.No.	Months of sowing	RTD ¹	PTU ²	Fresh root yield Kg/ha ³
1.	January	143.3	4481	18073
2.	February	148.1	4792	17123
3.	March	142.6	4796	16583
4.	April	131.2	4863	14633
5.	May	125.2	3704	14516
6.	June	119.9	899	17818
7.	July	121.6	850	18803
8.	August	115.7	836	17060
9.	September	115.0	432	19935
10.	October	110.1	87	25976
11.	November	113.2	950	23613
12.	December	119.5	1220	22773

CORRELATION :

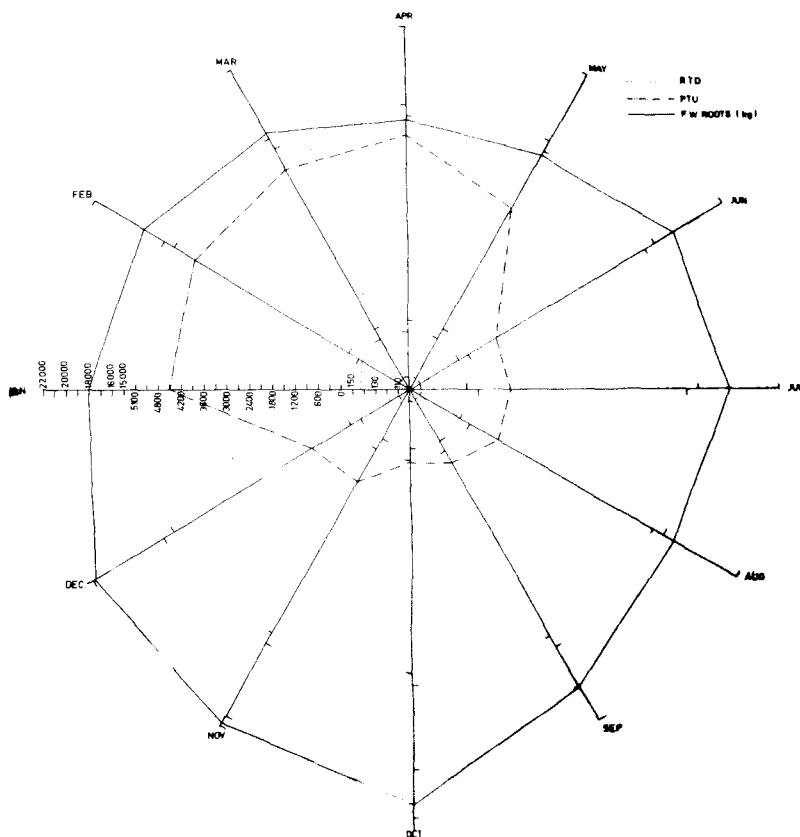
PTU and root yield = $r = (-) 0.6803^*$

RTD and root yield = $r = (-) 0.6432^*$

Note: 1&2 : RTD and PTU were calculated for the entire crop duration from sowing to harvest.

3 : Harvest at 120 days from sowing.

FIG. 3 EFFECT OF MONTHS OF SOWING ON RTD, PTU AND FRESH WEIGHT OF THE ROOTS



A high RTD was noted in February (148.1) followed by January (143.3) and March (142.6). The RTD value was low in October (110.1) and November (113.2). The RTD value was correlated with the fresh root yield and it was found that a high negative correlation existed between the two factors ($r = (-) 0.6432$).

4:1:1:17 Photo thermal unit (PTU)

PTU was higher in April (4863), followed by March and February (4796, 4792) respectively. The PTU value was found to decrease from 4863 during January to 87 in October and thereafter there was a slight rise (Table 12; Fig.3). The PTU value from June to September was also below one thousand. The lowest PTU value was obtained in October (87) which was followed by September (432) and August (836). The relationship of PTU and fresh root yield showed a negative relationship ($r = (-) 0.6803$).

4:1:2 Chemical constituents

The biochemical make up of both the roots and foliage in the monthly sowing experiment was studied and the results are presented below.

4:1:2:1 Nitrogen content in the leaves and roots

In the leaves during the initial phase of the growth (30th day), the nitrogen content was high in October

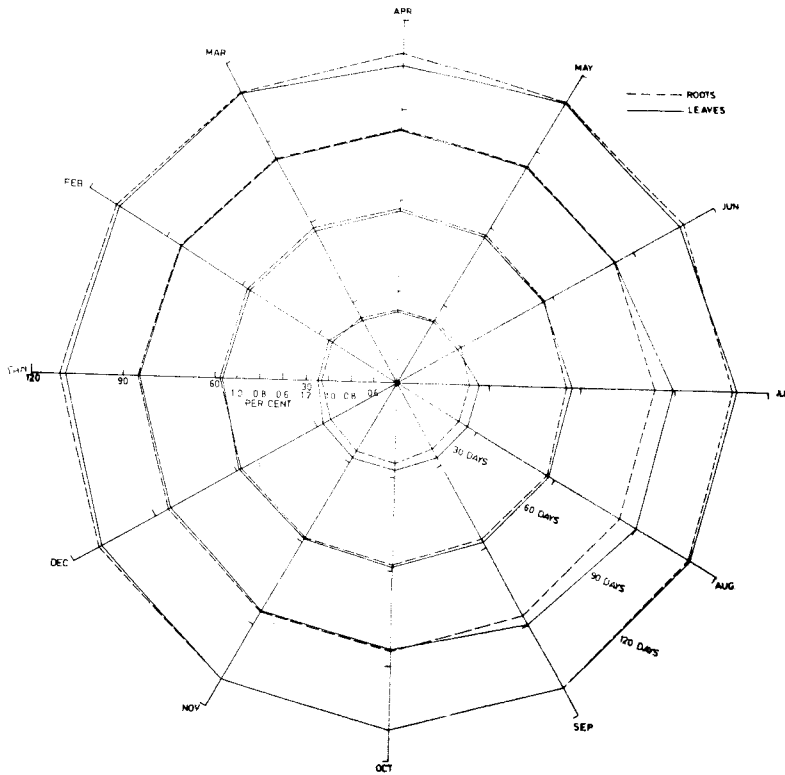
sowing (1.148%), followed by November sowing (1.147%) and December sowing (1.142%). A low nitrogen content was recorded in the crop sown in June (1.018%) followed by May sowing (1.029%). Though the nitrogen content ranged between 1.018 to 1.148%, the treatment influence was not significant. In the second phase, leaf nitrogen was high in October sowing (1.163%), followed by November and December sowing with 1.162% and 1.161%. June sown crop had a low leaf nitrogen content of 1.101%. In August sowing the leaf nitrogen content in the third phase (90 days) was high with 1.242%, followed by July sowing (1.231%). Crop sown in October, November and December registered lower values than those sown in July and August sowing. Nitrogen content in this phase was found to be lower than at the 60th day after sowing. In the fourth phase, leaf nitrogen content was still lower than the values at 90th day after sowing; October sowing registered high leaf nitrogen content (0.942%). But the range of values in the different months of sowing was only minimal (0.792 to 0.942%). The leaf nitrogen content, although varying to some degree in the different growth stages among the various months of sowing, did not attain statistical significance (Table 13; Fig.4).

In respect of root nitrogen content, in the early phase (30th day), October sowing had high content (1.079%), followed by November (1.078%) and December (1.069%). The

Table 13 EFFECT OF MONTHS OF SOWING ON NITROGEN CONTENT IN THE LEAVES AND ROOTS

S.No.	Months of sowing	Nitrogen content in the leaves (%) during stages (days after sowing)				Nitrogen content in roots (%) during stages (days after sowing)			
		30th	60th	90th	120th	30th	60th	90th	120th
1.	January	1.093	1.131	1.051	0.892	1.062	1.151	1.064	0.949
2.	February	1.091	1.130	1.050	0.891	1.061	1.149	1.061	0.931
3.	March	1.033	1.115	1.042	0.872	1.053	1.139	1.057	0.929
4.	April	1.031	1.110	1.031	0.792	1.048	1.133	1.049	0.914
5.	May	1.029	1.103	1.041	0.892	1.041	1.129	1.048	0.907
6.	June	1.018	1.101	1.037	0.864	1.039	1.117	1.042	0.901
7.	July	1.120	1.137	1.231	0.927	1.032	1.087	1.042	0.901
8.	August	1.129	1.149	1.242	0.938	1.043	1.129	1.043	0.927
9.	September	1.132	1.152	1.132	0.939	1.047	1.131	1.047	0.939
10.	October	1.148	1.163	1.062	0.942	1.079	1.149	1.069	0.937
11.	November	1.147	1.162	1.061	0.941	1.078	1.156	1.068	0.942
12.	December	1.142	1.161	1.059	0.931	1.069	1.152	1.067	0.953
S.E.		NS	NS	NS	NS	NS	0.021	NS	NS
CD (p=0.05)							0.063		

FIG. 4 EFFECT OF MONTHS OF SOWING ON NITROGEN CONTENT
IN LEAVES AND ROOTS



root nitrogen was low in July sowing with 1.032%. However, the values did not differ significantly. In the second phase, November sowing registered high root nitrogen of 1.156%, followed by December (1.152%) and October (1.149%). July sowing registered very low root nitrogen (1.087%). In this phase the difference in the root nitrogen content ranged within narrow limits from 1.087% to 1.156%. In the third phase, the root nitrogen content progressively declined in all the months of sowing and the highest value was noted in October sowing (1.069%) and the lowest in June and July sowings (1.042%). In the final phase (120th day) root nitrogen content was still lower than the previous phase and December sowing had a high nitrogen content (0.953%) followed by November (0.942%) and October (0.937%). Except at the phase of 60 days after sowing, the values did not show significant differences in the other phases (Table 13; Fig. 4).

4.1:2:2 Phosphorus content in the leaves and roots

Only in the initial phase (30 days), the leaf phosphorus content showed significant differences among the months of sowing. Leaf phosphorus content was high in October sowing (0.115%) and was very low in May sowing (0.083%). During the hotter part of the year from February to June, the leaf phosphorus was relatively very much less. In the second phase, there was a decline in the phosphorus

content in the crops sown in all the months. The leaf phosphorus content was the least in May sowing (0.073%) and October sowing showed a high content (0.095%). In the third phase (90th day) leaf phosphorus content was found to be lower than the previous phase. December sowing recorded a high phosphorus content (0.090%) whereas May sowing had only 0.053%. In the last phase the same trend was noted and the values were lower than the previous phase. The values in the last three phases did not differ significantly (Table 14).

The root phosphorus content in the initial phase was found to be greater in the crop sown from May to December and was high in October sowing (0.117%), followed by November (0.115%) and September (0.114%) whereas March sowing had a low content (0.082%). In the second phase, the phosphorus content was slightly higher than the previous phase and October sowing registered the highest value (0.136%) followed by November (0.135%) whereas April sowing had only 0.099% of phosphorus. In the third phase, the phosphorus content was found to decline from the previous phase. Root phosphorus content was high in October sowing (0.129%), followed by November (0.126%) and December (0.120%) whereas March sowing registered only a low value of 0.089%. In the final phase, a similar trend was observed and the root phosphorus content was still lower than the previous phase.

Table 14 EFFECT OF MONTHS OF SOWING ON THE PHOSPHORUS CONTENT IN THE LEAVES AND ROOT

S.No. sowing	Phosphorus content in the leaves (%) during stages (days after sowing)			Phosphorus content in roots (%) during stages (days after sowing)		
	30th	60th	90th	120th	30th	60th
1. January	0.102	0.087	0.067	0.056	0.098	0.129
2. February	0.097	0.082	0.063	0.052	0.093	0.126
3. March	0.092	0.081	0.061	0.049	0.087	0.105
4. April	0.087	0.079	0.057	0.042	0.082	0.099
5. May	0.083	0.073	0.053	0.043	0.093	0.103
6. June	0.092	0.083	0.058	0.047	0.107	0.115
7. July	0.098	0.087	0.059	0.049	0.109	0.117
8. August	0.099	0.088	0.062	0.051	0.112	0.121
9. September	0.101	0.094	0.063	0.053	0.114	0.127
10. October	0.115	0.095	0.075	0.062	0.117	0.136
11. November	0.113	0.092	0.072	0.062	0.115	0.135
12. December	0.110	0.090	0.090	0.068	0.111	0.132
S.E.	0.008	NS	NS	NS	NS	0.0266
CD (p=0.05)	0.025					0.0789

Significant differences among the months of sowing were noted only at the stage of 60 days after sowing (Table 14).

4.1:2:3 Potassium content in the leaves and roots

In the initial phase (30th day) the potassium content was high in October sowing (2.15%) followed by November (2.13%) and December sowing (2.10%) whereas May sowing had only 1.72% of leaf potassium. The differences were significant. Greater leaf potassium content was obtained in the second phase than the previous phase. The leaf potassium content was high in the October sowing (3.88%), followed by November (3.82%) and September (3.72%). Slightly lower potassium content was recorded in the third phase and its content was high in October sowing (3.85%) closely followed by November and September sowing (3.80% and 3.73%) whereas April sowing had only 3.34%. There was again a declining trend in leaf potassium content during the fourth phase when compared to the previous phase. But leaf potassium content in the different months of sowing followed the same trend as the previous phases. However treatment effects were not significant at this phase (Table 15).

In the roots, in the early phase (30th day) potassium content was high in April sowing (3.23%), followed by July (3.19%) whereas October and November sowings showed 3.08% and 3.07% only but the differences were not significant.

Significant differences among the months of sowing were noted only at the stage of 60 days after sowing (Table 14).

4:1:2:3 Potassium content in the leaves and roots

In the initial phase (30th day) the potassium content was high in October sowing (2.15%) followed by November (2.13%) and December sowing (2.10%) whereas May sowing had only 1.72% of leaf potassium. The differences were significant. Greater leaf potassium content was obtained in the second phase than the previous phase. The leaf potassium content was high in the October sowing (3.88%), followed by November (3.82%) and September (3.72%). Slightly lower potassium content was recorded in the third phase and its content was high in October sowing (3.85%) closely followed by November and September sowing (3.80% and 3.73%) whereas April sowing had only 3.34%. There was again a declining trend in leaf potassium content during the fourth phase when compared to the previous phase. But leaf potassium content in the different months of sowing followed the same trend as the previous phases. However treatment effects were not significant at this phase (Table 15).

In the roots, in the early phase (30th day) potassium content was high in April sowing (3.23%), followed by July (3.19%) whereas October and November sowings showed 3.08% and 3.07% only but the differences were not significant

among the months of sowing. A significantly higher increase in potassium content was noted in the second phase and April sowing registered the highest leaf content (3.98%), followed by October sowing (3.97%) and the least was noted in August sowing (3.39%). The third phase in general, was characterised by slightly higher values than the previous phase. April sowing registered significantly the highest value (4.20%), followed by May (4.17%) whereas a low content was seen in February sowing (3.52%). In the final phase April sowing registered a high potassium content (4.38%) followed by March (4.27%) and a low potassium content was seen in August sowing (3.52%). The values ranged within narrow limits at this phase (Table 15).

4:1:3 Quality attributes

The reducing sugar, non-reducing sugar and total sugars were analysed in the dried tubers and the data are presented in Table 16; Fig.3).

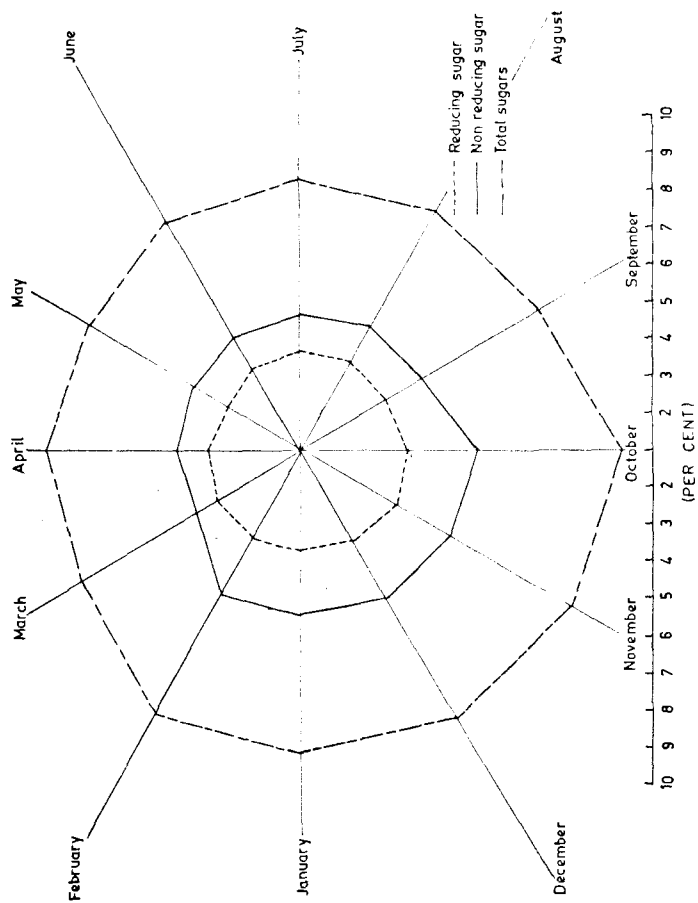
4:1:3:1 Reducing sugar

Highly significant differences were obtained in the reducing sugar content among the different months of sowing. A high content of reducing sugar was noted in the October sowing (3.92%) followed by November (3.86%) and December sowing (3.82%). The roots of May sown crop recorded only a low value (3.33%).

Table 16 EFFECT OF MONTHS OF SOWING ON REDUCING SUGAR,
NON-REDUCING SUGAR AND TOTAL SUGAR
 (Per cent on Dry Weight Basis)

S.No.	Months of sowing	Reducing sugar	Non-reducing sugar	Total sugar
1.	January	3.71	5.43	9.14
2.	February	3.65	5.40	9.05
3.	March	3.64	4.34	7.98
4.	April	3.54	4.31	7.85
5.	May	3.33	4.30	7.63
6.	June	3.54	4.54	8.08
7.	July	3.62	4.62	8.24
8.	August	3.69	4.75	8.44
9.	September	3.71	4.82	8.53
10.	October	3.92	5.82	9.74
11.	November	3.86	5.62	9.48
12.	December	3.82	5.60	9.42
	S.E.	0.03	0.072	NS
	CD (P=0.05)	0.09	0.216	

Fig.5 Effect of months of sowing on reducing, non-reducing and total sugars



4:1:3:2 Non-reducing sugar

Compared to the content of reducing sugar, the non-reducing sugar content was higher. October sowing registered the highest non-reducing sugar content of 5.82%, which was closely followed by November (5.62%) and December (5.60%), whereas May sowing had only 4.31% which was the lowest among the treatments. The effect of months of sowing was significant.

4:1:3:3 Total sugars

The total sugar content was high in the October sown crop (9.74%), closely followed by November (9.48%) and December (9.42%) sown crops. The content was low in the May sown crop 7.63%. The total sugar content did not differ significantly among the months of sowing.

4:1:3:4 Sugar fractions

Fructose and glucose content was analysed on fresh weight basis (Table 17).

The reducing sugar on fresh weight basis in the roots varied significantly among the different months of sowing. It was high in October sowing (18.18%), closely followed by November (17.50%), whereas it was low in July sowing (12.64%).

Table 17 EFFECT OF MONTHS OF SOWING ON REDUCING
SUGAR, GLUCOSE AND FRUCTOSE CONTENT IN
THE ROOTS
 (Per cent on fresh weight basis)

S.No.	Months of sowing	Reducing sugar (%)	Glucose(%) *	Fructose(%) *
1.	January	14.16	19.75	82.25
2.	February	12.90	19.50	80.50
3.	March	13.66	19.75	80.25
4.	April	13.16	19.08	80.92
5.	May	14.20	17.25	82.75
6.	June	13.66	19.08	81.92
7.	July	12.64	20.72	79.28
8.	August	12.69	19.48	80.52
9.	September	13.88	19.33	80.67
10.	October	18.18	16.28	83.72
11.	November	17.50	14.53	85.47
12.	December	14.77	19.73	80.27
	S.E.	0.631	NS	NS
	CD (P=0.05)	1.893		

* Concentration expressed as a percentage
 of the total sugars.

4:1:3:5 Glucose content

The glucose content was the lowest in November sowing (14.53%) followed by October sowing (16.28%). A high glucose content was obtained in July sowing (20.72%). The hotter part of the year registered a higher sugar content ranging from 19.08 to 19.75% whereas the cooler part of this year showed an inconsistent trend.

4:1:3:6 Fructose content

A high percentage of fructose was obtained in November sowing (85.47%) followed by October (83.72%). A low percentage was recorded in July sowing (79.23%). The other months of sowing showed only slight differences and the treatment effects were not significant.

Crude fibre content, bitter principles, starch content and specific gravity of infusions

The crude fibre content, bitter principles, starch content and specific gravity of the chicory infusion were analysed and the data are presented in Table 18; Fig. 6..

4:1:3:7 Crude fibre content

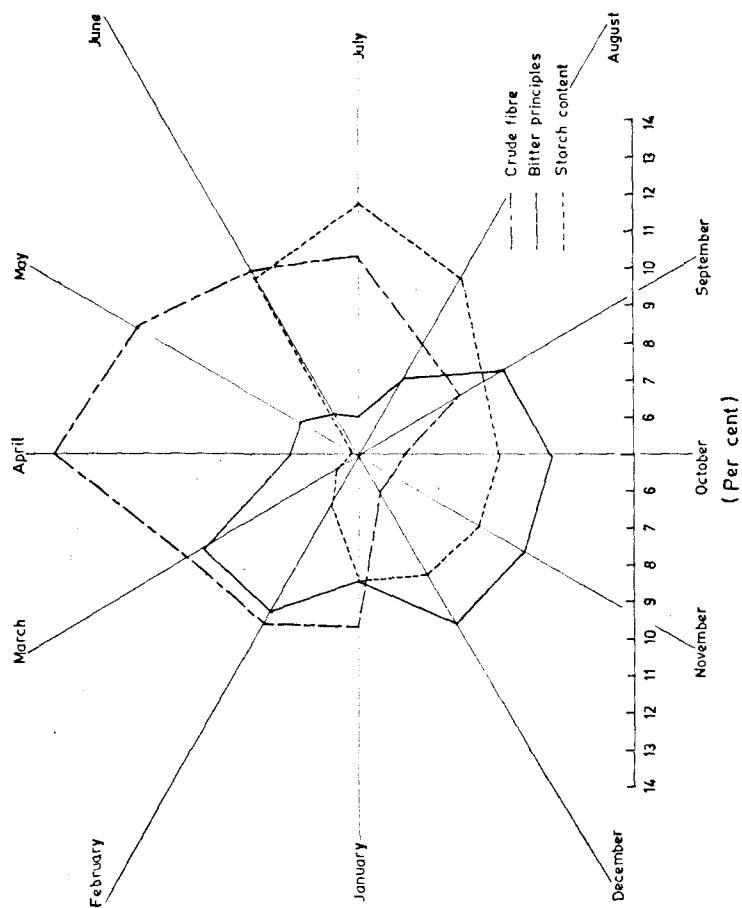
A significantly high crude fibre content was noted in April sowing (13.2%) which was followed by May (11.9%), June (10.7%) and March (10.4%). Crude fibre content was the least in November sowing (6.0%) which was less than half

Table 18 EFFECT OF MONTHS OF SOWING ON CRUDE
FIBRE CONTENT, BITTER PRINCIPLES
STARCH CONTENT AND SPECIFIC GRAVITY
OF INFUSION

S.No.	Months of sowing	Crude fibre (%)	Bitter princi- ples (%)	Starch content (%)	Specific gravity of the infu- sion*
1.	January	9.6	8.4	8.37	1.0165
2.	February	10.2	9.8	6.48	1.0182
3.	March	10.4	9.9	5.77	1.0197
4.	April	13.2	6.9	5.28	1.0191
5.	May	11.9	6.8	5.11	1.0199
6.	June	10.7	6.3	10.47	1.0201
7.	July	10.3	6.0	11.69	1.0209
8.	August	8.4	7.4	10.47	1.0217
9.	September	8.1	9.5	9.14	1.0217
10.	October	6.2	10.2	8.77	1.0232
11.	November	6.0	10.1	8.80	1.0201
12.	December	6.1	10.2	8.69	0.0198
	S.E.	0.329	0.205	0.214	NS
	CD (P=0.05)	0.987	0.615	0.543	

* The specific gravity of infusion of
coffee berries is 1.008.

Fig.6 Effect of months of sowing on starch, crude fibre and bitter principles



that of April sowing. The crude fibre content in October and December sowings was also low (6.2% and 6.1%).

4:1:3:8 Bitter principles

The content of bitter principles was significantly high in October and December sowings with 10.2% and November sowing (10.1%). It was low in July and June sown crop (6.0% to 6.3%).

4:1:3:9 Starch content

The starch content was high in July sowing (11.69%) followed by June and August sowings (10.47%). Low starch content was noted in May (5.11%) and April sowings (5.28%). The differences were significant.

4:1:3:10 Specific gravity of infusion

The specific gravity of infusion obtained from chicory roots was comparable with that of coffee berries. The specific gravity of the coffee berries was 1.008 and the chicory roots obtained from October sowing showed the highest value (1.0232), followed by September and August sowing (1.0217). The specific gravity of the infusion was low in the roots obtained from January sown crop (1.0165) and February crop (1.0182). However the differences were not significant.

4:1:3:11 Protein content (Table 19)

In the chicory leaves, protein content was significantly high in the January sown crop (3.24%) which

Table 19 EFFECT OF MONTHS OF SOWING ON THE
PROTEIN CONTENT IN CHICORY LEAVES
AND ROOTS

S.No.	Months of sowing	<u>Protein per cent</u>	
		Leaves	Roots
1.	January	3.24	4.13
2.	February	3.09	4.21
3.	March	3.08	4.01
4.	April	3.02	3.08
5.	May	2.03	3.07
6.	June	2.15	2.85
7.	July	2.48	3.08
8.	August	2.68	3.20
9.	September	2.91	3.41
10.	October	2.98	4.37
11.	November	3.07	4.41
12.	December	3.04	4.81
	S.E.	0.019	0.023
	C.D. (P=0.05)	0.059	0.069

was closely followed by February and March sowings with 3.09% and 3.08% respectively. A moderate quantum of protein was noted in the November and December sown crop (3.07% and 3.04%) with October sowing ranking next with 2.95%. In the chicory roots the protein content was significantly high in the December sown crop (4.81%) followed by November (4.41%) and October sown crop (4.37%) and was low in the June sown crop (2.85%).

4:1:4 Enzyme Activity

The IAA oxidase, peroxidase and catalase activity were estimated in roots and leaves. The data are presented in Table 20; Fig. 78.

4:1:4:1 IAA oxidase

The IAA oxidase activity was high in the May sown crop (315.67) followed by April (312.67) and March (303.0) indicating higher enzymatic activity in the warmer part of the year. Low values were obtained in the leaves of crops sown in October (215.67), November (223.17) and December (231.0)

In the roots, IAA oxidase activity was high in the May sown crop (155.0), followed by April (151.0) and low activity was recorded in December, November and October (80.0, 82.0) and 86.6 respectively. In general, only about less than half of the IAA oxidase activity was found in the roots compared to leaves. The IAA oxidase activity both in the leaves and roots showed significant differences among the different months.

Fig.7 Effect of months of sowing on IAA oxidase, peroxidase and catalase activity in leaves

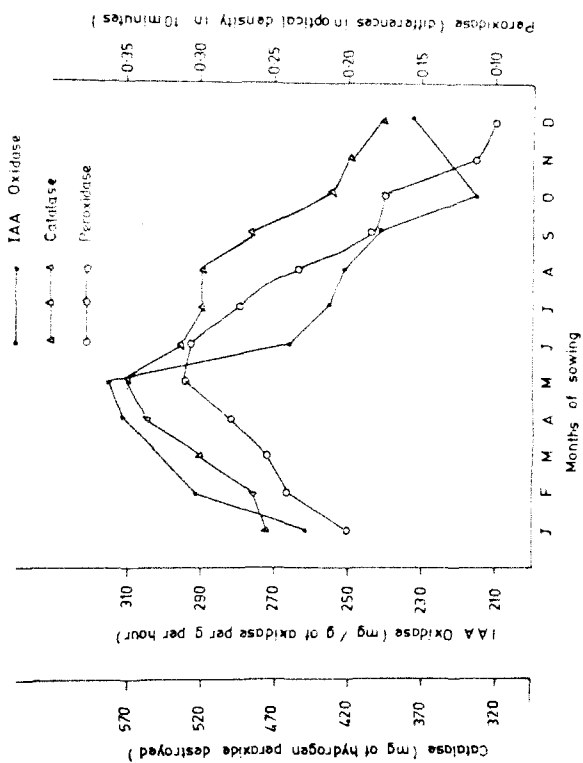
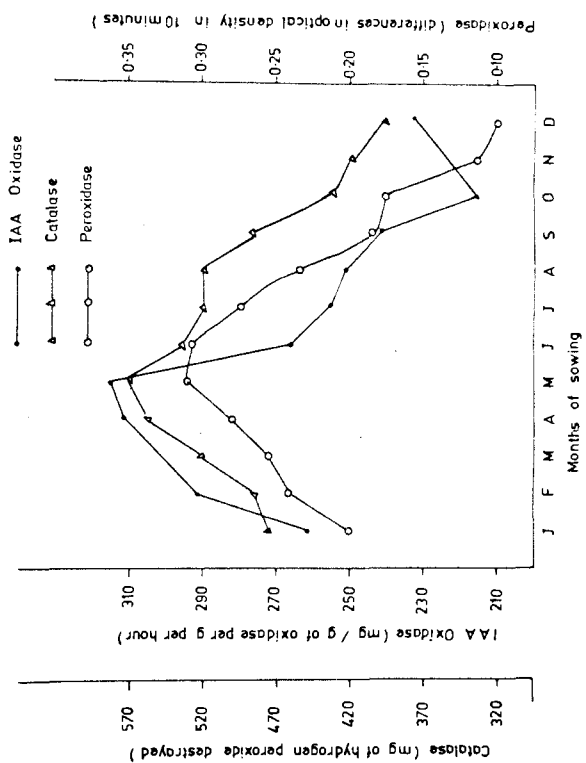
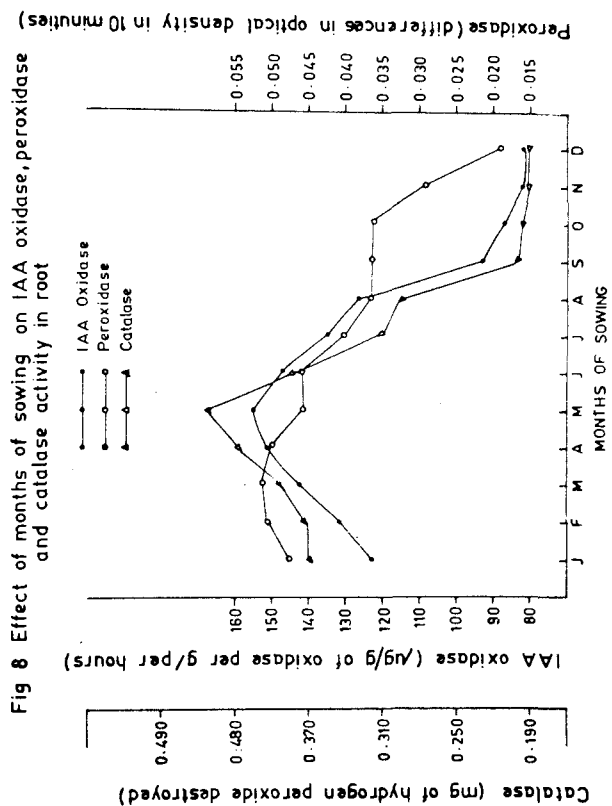


Fig.7 Effect of months of sowing on IAA oxidase, peroxidase and catalase activity in leaves





4:1:5 Endogenous hormonal changes (Table 21; Fig.9)

In the initial phase, (30th day) auxin activity was high in the October sown crop in leaves (153%), followed by September (150%) and November (142%) and was low in the March sown crop (102%). In this phase, low activity was noted in the crops sown from January to June. In the roots auxin activity was high in the November sown crop (153%) which was closely followed by September and October sown crop with 149%. In the root also March sown crop recorded the lowest auxin activity (103%).

In the second phase (60th day), the auxin activity was high in the leaves of October sown crop (153%) and was the least in the March sown crop (101%). In the roots, auxin activity was high in September sown crop (153%), and April sown crop recorded the least value (102%).

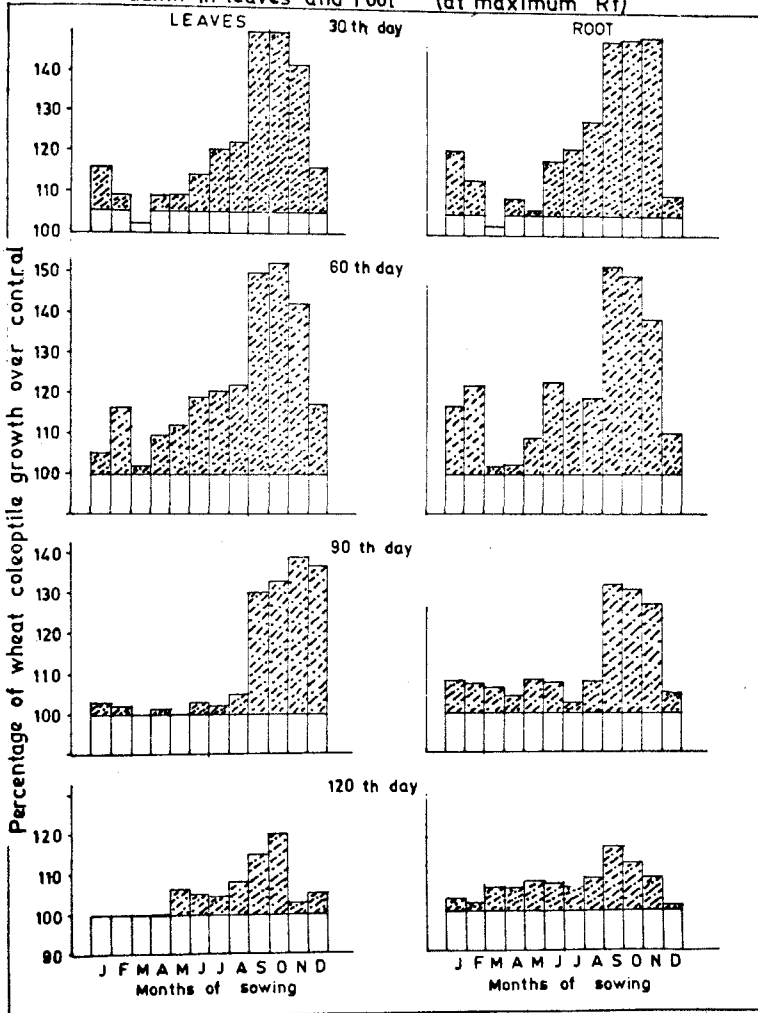
In the third phase (90th day), high leaf auxin activity was observed in the November sown crop (138%) which was closely followed in the October sown crop (133%), but the auxin content appeared to be negligible in crops sown from March to May. In the roots, auxin activity was high in September sown crop (133%), followed by October sown crop (132%) whereas low activity was observed in the April sown crop (104%).



Table 21 WHEAT COLEOPTILE BIOASSAY FOR AUXINS IN LEAVES AND ROOTS
IN DIFFERENT MONTHS
 (Percentage of wheat coleoptile growth over control)

S.No.	Months of sowing	Percentage of wheat coleoptile growth over control during stages (days after sowing)											
		30th day		60th day		90th day		120th day					
		Leaves	Roots	Leaves	Roots	Leaves	Roots	Leaves	Roots	Leaves	Roots	Leaves	Roots
1.	January	117	121	105	117	103	108	100	103				
2.	February	109	113	116	121	102	107	100	102				
3.	March	102	103	101	102	100	106	100	106				
4.	April	109	108	109	102	101	104	100	106				
5.	May	109	106	112	109	100	108	106	108				
6.	June	114	119	119	123	103	107	105	106				
7.	July	120	122	120	119	102	103	104	106				
8.	August	122	129	122	119	105	109	108	109				
9.	September	150	149	150	153	130	133	115	116				
10.	October	153	149	153	150	133	132	120	112				
11.	November	142	153	142	139	138	127	102	108				
12.	December	117	110	117	110	107	105	105	101				

Fig.9 Histograms showing wheat coleoptile bioassay for auxin in leaves and root (at maximum Rf)



In the final phase (120th day), auxin activity was seen to have been reduced compared to the previous stages of growth and auxin was practically absent in the leaves from January to April sowings. There was only a little auxin in the October sown crop (120%) and September sown crop (115%). In the roots also auxin activity was low, of which a greater value was noted in September sown crop (116%).

4:1:5:1 Auxin content

The data on auxin content (IAA equivalent) are presented in Table 22. The auxin content was generally high in the initial and second phases and was more in the roots than in the leaves.

In the first phase (30th day), leaf auxin content was high in the October sown crop (4.2 $\mu\text{g/g}$) followed by November (4.0 $\mu\text{g/g}$) and was low in the January sown crop (0.5 $\mu\text{g/g}$). The auxin content in the root was the highest in the September sown crop (4.2 $\mu\text{g/g}$), followed by October and November with 3.9 $\mu\text{g/g}$, whereas January sown crop registered a very low auxin content (0.9 $\mu\text{g/g}$).

In the second phase (60 days after sowing) the leaf auxin content was higher than the previous phase in crops sown in January, May and July to November. The highest value was noted in October sown crop (4.9 $\mu\text{g/g}$), followed by November crop (4.4 $\mu\text{g/g}$). Here again, January sown crop had a very low auxin content. The auxin content in the roots

Table 22 EFFECT OF MONTHS OF SOWING ON AUXIN CONTENT IN ROOTS AND LEAVES
(IAA equivalent $\mu\text{g/g}$ on fresh weight basis during stages (days after sowing))

S.No.	Months of sowing	30th day		60th day		90th day		120th day	
		Leaves	Roots	Leaves	Roots	Leaves	Roots	Leaves	Roots
1.	January	0.5	0.9	0.8	1.9	-	0.5	-	0.7
2.	February	1.3	1.7	1.2	1.2	-	0.8	-	0.9
3.	March	1.6	1.9	1.3	1.0	-	0.7	-	0.6
4.	April	1.9	2.2	1.5	1.7	-	0.6	-	0.3
5.	May	2.2	2.4	2.4	2.6	1.9	2.1	1.9	1.9
6.	June	2.9	3.2	2.7	2.9	3.3	2.2	2.2	2.3
7.	July	3.0	3.4	3.2	3.0	3.1	3.0	2.1	2.4
8.	August	3.5	3.7	3.7	3.9	3.0	3.2	2.7	2.9
9.	September	3.9	4.2	4.2	4.1	4.1	4.3	4.0	4.3
10.	October	4.2	3.9	4.9	4.7	4.3	4.7	4.1	4.4
11.	November	4.0	3.9	4.4	3.9	3.9	3.8	3.2	3.6
12.	December	3.2	3.0	3.0	3.2	2.0	2.2	2.0	2.2

was less than the leaf content in most of the months at this phase. It was high in October sown crop (4.7 $\mu\text{g/g}$) and September sown crop (4.1 $\mu\text{g/g}$). January and March sown crops recorded very low values (1.0 $\mu\text{g/g}$).

In the third phase, the leaf auxin content was high in the October sown crop (4.3 $\mu\text{g/g}$) and September sown crop (4.1 $\mu\text{g/g}$) and there was no auxin content in the crops raised from January to April. The auxin content in the roots recorded a wide variation ranging from 0.5 to 4.7 $\mu\text{g/g}$. The highest value was noted in the October sown crop.

In the fourth phase, leaf auxin content was less than the previous phase. There was no auxin content during January to April. A high (4.1 $\mu\text{g/g}$) level of auxin content was recorded in October sown crop, followed by September sown crop with 4.0 $\mu\text{g/g}$. In the roots also a high auxin content was observed in the October sown crop (4.4 $\mu\text{g/g}$) followed by September crop (4.3 $\mu\text{g/g}$).

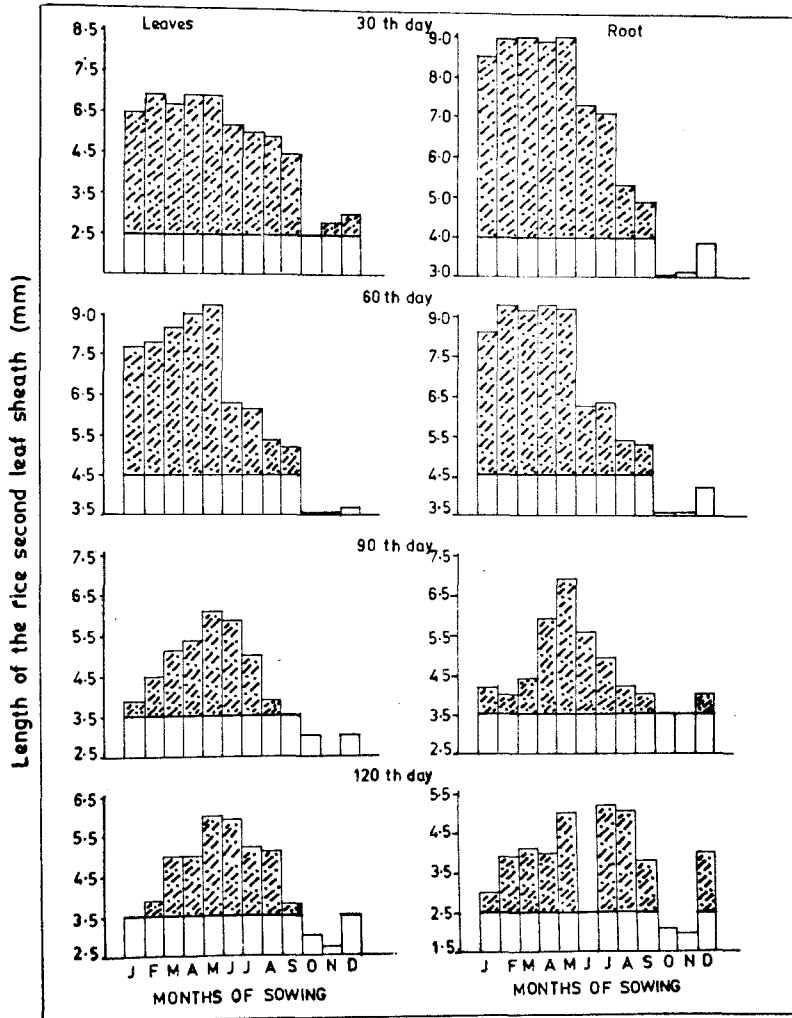
4:1:5:2 Gibberellin activity (Table 23; Fig. 10)

In the first phase, leaf gibberellin activity was the highest in April and May sown crops (6.9 mm), followed by February (6.8 mm) and March (6.7 mm). Its activity was low in the October sown crop (2.5 mm). In the roots, May and February months sowings led the rest with 9.2 mm, followed by March (9.0 mm). The October sown crop registered

Table 23 RICE LEAF SHEATH BIOMASSAY FOR GIBBERELLINS, LENGTH OF THE SECOND LEAF SHEATH ON SEVENTH DAY (mm) DURING STAGES (Days after sowing)

S.No.	Months of sowing	30th day		60th day		90th day		120th day	
		Leaves	Roots	Leaves	Roots	Leaves	Roots	Leaves	Roots
1.	January	6.5	8.5	7.2	8.2	3.8	4.2	3.5	3.0
2.	February	6.8	9.2	7.5	9.9	4.5	4.0	3.9	3.9
3.	March	6.7	9.0	8.2	9.8	5.2	4.9	5.0	4.1
4.	April	6.9	8.9	9.0	9.9	5.8	5.9	5.0	4.0
5.	May	6.9	9.2	9.2	9.5	6.2	6.9	6.0	5.0
6.	June	5.3	7.3	6.3	6.2	5.9	5.5	5.9	4.9
7.	July	5.0	7.1	6.2	6.4	4.0	4.9	5.3	5.2
8.	August	4.8	5.3	4.9	5.4	3.9	4.2	5.2	5.0
9.	September	4.5	4.9	4.6	5.3	3.5	4.0	3.9	3.8
10.	October	2.5	3.0	2.7	2.3	3.0	2.5	3.0	2.2
11.	November	2.7	3.2	2.5	2.2	2.5	2.0	2.9	2.0
12.	December	3.0	3.7	3.7	4.2	3.5	4.0	3.5	4.0

Fig.10 Histograms showing rice leaf sheath bioassay for gibberellins in leaves and root (at maximum Rf)



very low gibberellin activity (3.0 mm), followed by November and December (3.2 and 3.7 mm).

In the second phase, May sown crop had a high gibberellin activity, followed by April. Very low gibberellin activity was noted in the November sown crop, followed by October sown crop. In the roots a high activity was observed in February and March sown crops (9.9 mm) and very low activity in the November (2.2 mm) and October (2.3 mm) sown crops.

In the third phase (90 days after sowing), gibberellin activity was generally much less than the previous phases. High activity was observed in May (6.2 mm) and June (5.9 mm) sown crops and low activity in the November and October sown crops (2.5 mm and 3.0 mm). In the roots, high gibberellin activity was noted in May sown crop (6.9 mm) and low activity in November sown crop (2.0 mm).

In the fourth phase, May sown crop had a high gibberellin activity (6.0 mm), followed by June (5.9 mm) whereas it was much less in November (2.9 mm) and October (3.0 mm) sown crops. Comparatively the root gibberellin activity was lower than in the leaves and ranged between 2.0 mm to 5.2 mm. The highest activity was recorded in July and August sown crops.

4.1.5.3 Gibberellin content

The gibberellin like substances were analysed in the leaves and roots in the four phases and are presented in Table 24.

On the 30th day gibberellin content was high in April sown crop (26.3 $\mu\text{g/g}$) followed by May sown crop (25.9 $\mu\text{g/g}$) whereas its content was very low in October, November and December sowings (4.3, 5.5 and 6.2 $\mu\text{g/g}$ respectively). The roots in the first phase contained generally greater gibberellin content than the leaves. It was high in the April sown crop (28.3 $\mu\text{g/g}$) followed by May sown crop (26.2 $\mu\text{g/g}$). November sown crop recorded the least value (5.9 $\mu\text{g/g}$). In general October, November and December sown crops registered very low gibberellin contents.

In the second phase, a slightly higher content of gibberellin like substances was noted than in the previous phase. The value was high in the April sown crop (28.2 $\mu\text{g/g}$), followed by May (27.9 $\mu\text{g/g}$). Very low values were recorded in October (4.0 $\mu\text{g/g}$), November (4.5 $\mu\text{g/g}$) and December (4.9 $\mu\text{g/g}$) sown crops. In the roots also, high gibberellin like substances were recorded in April (30.1 $\mu\text{g/g}$) and May sown crops (30.0 $\mu\text{g/g}$) whereas the least content was noticed in October, November and December (4.3, 4.9 and 5.2 $\mu\text{g/g}$) sown crops.

Table 24 EFFECT OF MONTHS OF SOWING ON GIBBERELLIN CONTENT (µg/q on fresh weight basis) DURING STAGES (days after sowing)

S.No.	Months of sowing	30th day		60th day		90th day		120th day	
		Leaves	Roots	Leaves	Roots	Leaves	Roots	Leaves	Roots
1.	January	18.9	20.3	19.2	20.6	16.3	18.5	15.2	16.3
2.	February	20.9	21.2	22.3	23.2	20.9	21.4	23.6	17.4
3.	March	24.3	25.7	24.9	25.8	23.8	24.2	24.2	20.9
4.	April	26.3	28.3	28.2	30.1	25.3	27.2	23.2	21.5
5.	May	25.9	26.2	27.9	30.0	22.2	25.9	21.3	20.5
6.	June	20.4	22.1	23.2	21.3	24.2	23.2	23.3	24.4
7.	July	18.9	20.7	20.9	18.9	20.5	21.2	20.6	18.7
8.	August	19.2	16.7	17.9	19.2	15.2	14.2	13.9	12.9
9.	September	10.1	16.2	10.3	8.5	10.9	9.3	10.3	9.6
10.	October	4.3	12.1	4.0	4.3	3.8	3.9	3.0	3.2
11.	November	5.5	5.9	4.5	4.9	3.9	4.2	3.5	3.9
12.	December	6.2	7.2	4.9	5.2	4.1	4.5	3.7	3.6

In the third phase, a high value for gibberellin like substances was observed in the April sown crop in leaves (25.3 $\mu\text{g/g}$) and roots (27.2 $\mu\text{g/g}$). Low values were observed in October sown crop (3.8 $\mu\text{g/g}$ in leaves and 3.9 $\mu\text{g/g}$ in roots).

In the final phase, higher amounts of gibberellin like substances were recorded in the March sown crop (24.2 $\mu\text{g/g}$), followed by June sown crop (22.3 $\mu\text{g/g}$) whereas its contents were very much less in October, November and December sown crops (3.0 $\mu\text{g/g}$, 3.5 $\mu\text{g/g}$ and 3.7 $\mu\text{g/g}$) respectively. In the roots June sown crop registered a high value 24.4 $\mu\text{g/g}$ and October, November and December sown crops had the least values (3.2, 3.9 and 3.6 $\mu\text{g/g}$).

4:1:5:4 Cytokinin activity (Table 25; Fig.11)

In the first phase (30 days after sowing) high cytokinin activity was noted in October sown crop (48), followed by November (46) and September (42), whereas its activity was less in April (15), May (17) and June sowings (19). The roots also showed the same trend but a high activity was seen in September (45), October (42) and November sowings (40). Here again, low activity was noted in the March sown crop (16).

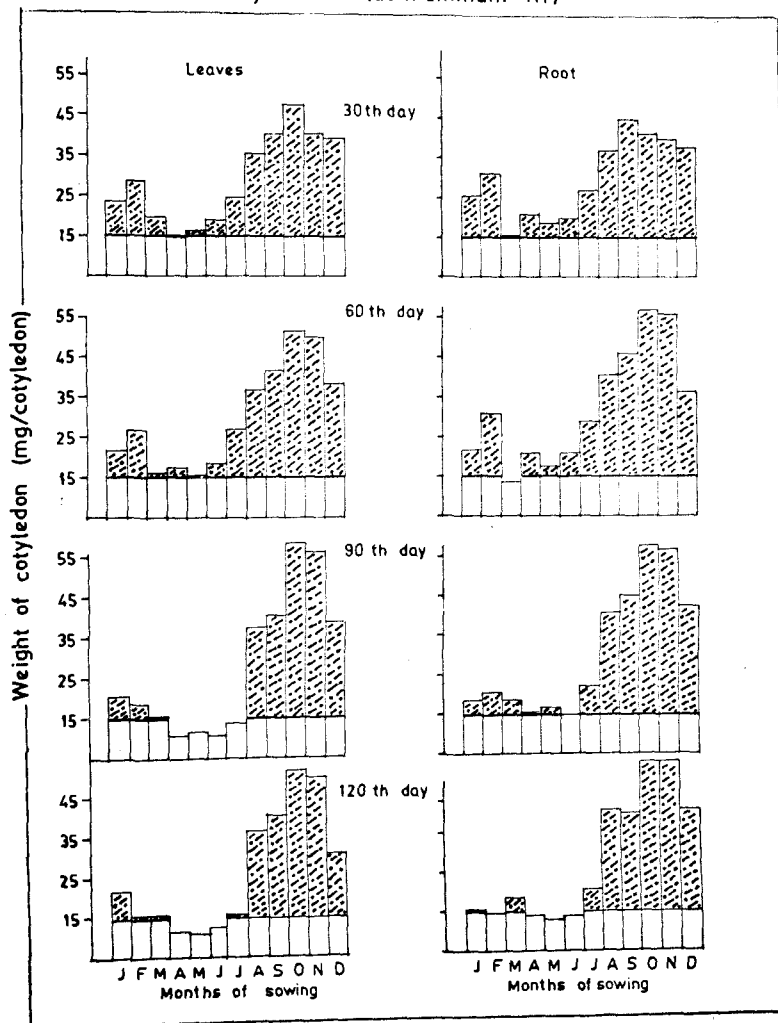
In the second phase also high leaf cytokinin activity was observed in October sown crop (52) which was closely followed by November (51) and September (44). A low

Table 25 RADISH COTYLEDON BIOMASSAY FOR CYTOKININ-WEIGHT OF RADISH COTYLEDON

DURING STAGES (days after sowing) (mg/cotyledon)

S.No.	Months of sowing	30th day		60th day		90th day		120th day	
		Leaves	Roots	Leaves	Roots	Leaves	Roots	Leaves	Roots
1.	January	24	27	23	23	21	19	22	17
2.	February	29	31	27	31	19	21	16	15
3.	March	20	16	16	13	17	19	16	19
4.	April	15	21	17	23	13	16	12	14
5.	May	17	19	16	18	14	17	12	13
6.	June	19	20	19	21	13	15	13	14
7.	July	25	27	27	29	19	24	16	21
8.	August	36	37	38	41	39	41	38	41
9.	September	42	45	44	46	41	45	42	40
10.	October	48	42	52	56	58	59	52	65
11.	November	46	40	51	55	52	58	50	62
12.	December	40	38	39	36	39	42	32	41

Fig.11 Histograms showing radish cotyledon bioassay for cytokinin (at maximum Rf)



activity was noted in May and March (16) and April sowings (17). In the roots also, October sowing led the rest with 55 mg/cotyledon and the lowest was noted in March sowing (13 mg). At this phase cytokinin activity in roots was generally higher than in the leaves.

In the third phase also October sowing scored over other months of sowing in the cytokinin activity (58), closely followed by November (52) and September (41). The crop sown in April and June registered a low cytokinin activity (13). Relatively a higher cytokinin activity was recorded in the roots than the leaves. The activity in the roots was high during October sowing with 59 mg/cotyledon closely followed by November sown crop (58 mg/cotyledon) and September (45 mg/cotyledon).

In the fourth phase, leaves had a generally lesser activity than the previous phases and its activity was maximum in the October sown crop (52 mg/cotyledon), followed by November crop (50 mg/cotyledon). The least cytokinin activity was seen in the April sown crop (12 mg/cotyledon). The roots had a higher cytokinin activity than the leaves and the value was 65 mg/cotyledon in the October sown crop and 62 mg/cotyledon in the November sown crop.

4:1:5:5 Cytokinin content

In the first phase, the cytokinin content was high in the October sown crop (0.439 $\mu\text{g/g}$) which was closely followed by November crop (0.419 $\mu\text{g/g}$). In the April sown

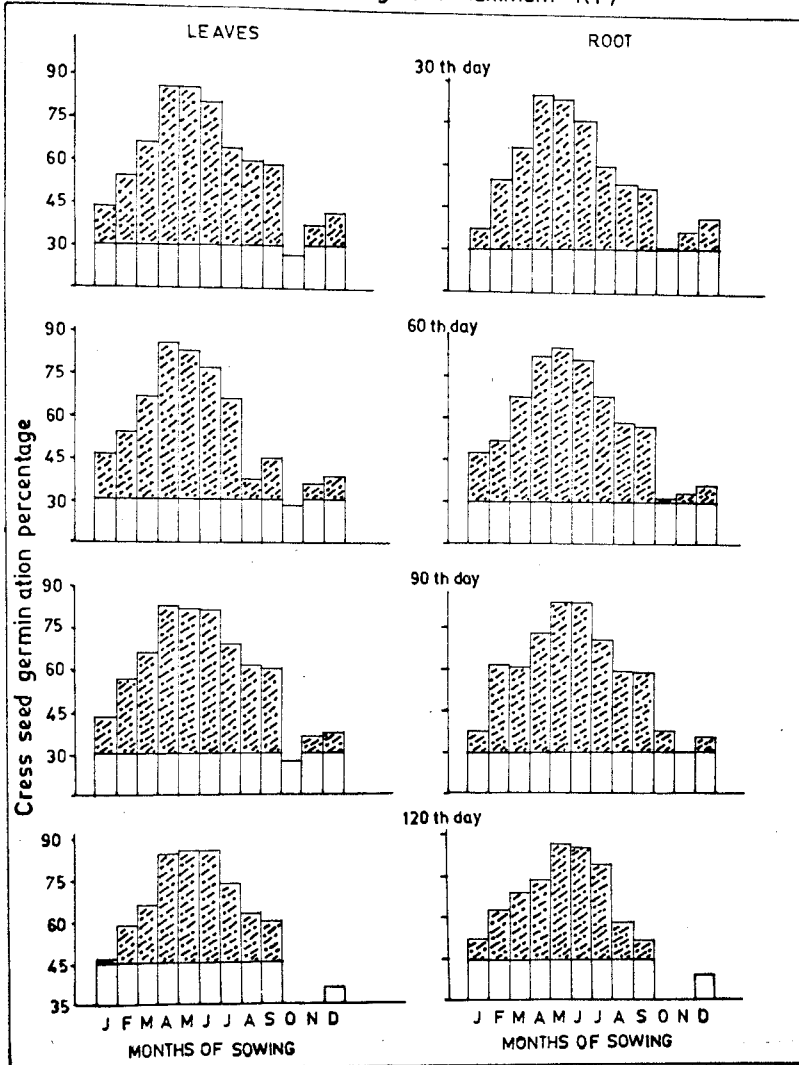
Table 26 EFFECT OF SOWING ON KINETIN EQUIVALENT ($\mu\text{g/g}$ on fresh weight basis)
DURING STAGES (days after sowing)

S.No.	Months of sowing	30th day		60th day		90th day		120th day	
		Leaves	Roots	Leaves	Roots	Leaves	Roots	Leaves	Roots
1.	January	0.201	0.213	0.217	0.207	0.214	0.217	0.215	0.217
2.	February	0.223	0.207	0.247	0.240	0.205	0.208	0.207	0.209
3.	March	0.207	0.197	0.195	0.196	0.192	0.193	0.193	0.193
4.	April	0.143	0.146	0.140	0.142	0.149	0.141	0.143	0.140
5.	May	0.162	0.163	0.163	0.165	0.162	0.162	0.160	0.162
6.	June	0.173	0.164	0.163	0.162	0.163	0.169	0.172	0.173
7.	July	0.179	0.179	0.183	0.162	0.182	0.193	0.183	0.182
8.	August	0.192	0.192	0.200	0.203	0.205	0.203	0.209	0.217
9.	September	0.283	0.224	0.224	0.223	0.224	0.223	0.227	0.227
10.	October	0.439	0.461	0.482	0.493	0.435	0.432	0.436	0.421
11.	November	0.419	0.422	0.402	0.412	0.401	0.409	0.392	0.395
12.	December	0.391	0.390	0.390	0.396	0.392	0.352	0.350	0.351

Table 27 CRESS SEED BIOASSAY FOR INHIBITORS. GERMINATION PERCENTAGE
DURING STAGES (days after sowing)

S.No.	Months of sowing	30th day		60th day		90th day		120th day	
		Leaves	Roots	Leaves	Roots	Leaves	Roots	Leaves	Roots
1.	January	44	40	46	48	44	40	46	50
2.	February	53	56	53	50	58	62	59	63
3.	March	67	69	69	70	68	61	69	73
4.	April	85	82	84	80	80	78	81	79
5.	May	85	81	80	82	79	82	82	85
6.	June	78	76	76	79	79	82	82	83
7.	July	66	60	68	65	71	73	74	78
8.	August	60	52	40	58	62	58	62	59
9.	September	59	51	45	57	60	59	60	55
10.	October	28	31	29	32	29	35	28	32
11.	November	35	35	39	34	39	32	32	30
12.	December	39	42	41	39	40	38	39	42

Fig.12 Histogram showing cress seed bioassay for inhibitors
germination percentage (at maximum Rf)



registered low value (28%), followed by November and December sowing (35% and 39%). In the roots also a similar pattern was seen with a little higher activity in the October sowing.

In the second phase, a high activity was noted in April sowing, both in leaves and roots (84% and 80%). The inhibitors activity was the lowest in the crops sown in October, November and December both in the roots and leaves.

In the third phase (90 days after sowing) and the final phase (120 days after sowing), the pattern of variations was similar to the previous phases.

In general, inhibitors activity was high in March, April, May sowings and low in October, November and December sowings (Table 27; Fig. 12).

4:1:5:7 Inhibitor content

In the initial phase, high ABA equivalent was recorded in April sown crop (1.90 ug/g) followed by May (1.82 ug/g) and June crop (1.78 ug/g). ABA content was the lowest in October sowing (0.03 ug/g). A similar pattern was observed in the roots in which the ABA content was in general higher than in leaves in most of the months.

In the second phase, in both leaves and roots high ABA content was noted in the April sown crop (1.98 ug/g) followed by May sown crop (1.80 ug/g) and June crop (1.70 ug/g). The content was low in October, November and December sown crops.

Table 28 EFFECT OF MONTHS OF SOWING ON ABA EQUIVALENT ($\mu\text{g/g}$ on fresh weight)

DURING STAGES (days after sowing)

S.No.	Months of sowing	30th day		60th day		90th day		120th day	
		Leaves	Roots	Leaves	Roots	Leaves	Roots	Leaves	Roots
1.	January	0.19	0.21	0.82	0.85	0.86	0.92	0.94	0.98
2.	February	0.24	0.28	0.94	0.95	1.02	1.07	1.19	1.21
3.	March	0.26	0.24	0.98	0.98	1.09	1.09	1.21	1.24
4.	April	1.90	1.92	1.98	2.01	2.02	2.22	3.02	3.76
5.	May	1.82	1.85	1.80	1.78	2.00	2.12	3.00	3.06
6.	June	1.78	1.72	1.70	1.72	1.74	1.76	2.24	2.06
7.	July	1.68	1.63	1.64	1.64	1.70	1.72	2.12	2.24
8.	August	1.02	1.21	1.04	1.08	1.43	1.40	1.42	1.32
9.	September	0.82	0.89	0.93	0.98	1.02	1.04	1.21	1.30
10.	October	0.03	0.04	0.61	0.60	0.72	0.74	0.81	0.86
11.	November	0.11	0.14	0.72	0.74	0.73	0.78	0.91	0.95
12.	December	0.17	0.19	0.69	0.79	0.80	0.85	0.95	0.98

In the third phase, high ABA content were recorded both in the roots and leaves in April sown crop (2.22 and 2.02 ug/g) and the values were lower in October, November and December sowings.

In the final phase, the ABA content was in general higher than in the previous phase and the highest value was noted in April sowing, both in leaves (3.02 ug/g) and roots (3.76 ug/g). The lowest values were noted in October sowing (0.81 ug/g) in leaves and (0.86 ug/g) in the roots.

In general, ABA like substances were high in the April, May and June sown crops the values being slightly higher in the roots than the leaves. In the crops sown in October, November and December a lower content than the other months of sowing was observed (Table 28).

TABLE-29
THE RELATIONSHIP BETWEEN PHOTOTHERMAL UNIT ON VARIOUS CHARACTERS

S.No.	CHARACTERS	CORRELATION COEFFICIENT	LEVEL OF SIGNIFICANCE	REGRESSION EQUATION
I. Growth and yield				
1.	Number of leaves	$r = -0.4761$	—	$\hat{Y} = 5749.55 - 115.31 X$
2.	Leaf area (dm ²)	$r = -0.3434$	—	$\hat{Y} = 6773.15 - 101.29 X$
3.	Bolted plants	$r = 0.8194$	••	$\hat{Y} = 843.42 + 93.83 X$
4.	Mean root weight (g/plant)	$r = -0.6056$	•	$\hat{Y} = 7239.18 - 58.59 X$
5.	Length of the root (cm)	$r = -0.7333$	••	$\hat{Y} = 8913.83 - 186.81 X$
6.	Girth of the root (cm)	$r = -0.7951$	••	$\hat{Y} = 6615.19 - 227.85 X$
7.	Fresh weight of tops (kg/ha)	$r = -0.7239$	••	$\hat{Y} = 10197.48 - 0.3417 X$
8.	Total fresh weight of roots (kg/ha)	$r = -0.6803$	•	$\hat{Y} = 9488.53 - 0.3787 X$
9.	Dry weight of tops (Kg/ha)	$r = -0.7214$	••	$\hat{Y} = 9182.72 - 0.9378 X$
10.	„ „ „ roots „	$r = -0.7151$	••	$\hat{Y} = 8110.12 - 0.9787 X$
11.	Harvest index	$r = -0.4895$	—	$\hat{Y} = 45670.47 - 0.4895 X$
12.	NAR	$r = -0.7177$	••	$\hat{Y} = 10957.12 - 0.7176 X$
13.	RGR	$r = -0.2190$	—	$\hat{Y} = 5401.62 - 17617.68 X$
II Nutrients				
1.	Leaf N at 120 days (%)	$r = -0.7141$	••	$\hat{Y} = 30886.79 - 31672.81 X$
2.	Root N at 120 days (%)	$r = -0.1751$	—	$\hat{Y} = 2546.28 - 133.24 X$
3.	Leaf P „	$r = -0.4585$	—	$\hat{Y} = 8396.73 - 11490.67 X$
4.	Root P „	$r = -0.6109$	•	$\hat{Y} = 9190.22 - 79664.03 X$
5.	Leaf K „	$r = -0.6653$	•	$\hat{Y} = 26522.05 - 7151.59 X$
6.	Root K „	$r = -0.4109$	—	$\hat{Y} = 7250 - 2496.81 X$
III PTU ON QUALITY				
1.	Reducing sugar (%)	$r = -0.4816$	—	$\hat{Y} = 24239 - 597.07 X$
2.	Non-reducing sugar (%)	$r = -0.3088$	—	$\hat{Y} = 7642 - 1071.48 X$
3.	Total sugars (%)	$r = -0.3563$	—	$\hat{Y} = 10920.87 - 995.76 X$
4.	Reducing sugar (FWB) (%)	$r = -0.9516$	••	$\hat{Y} = 8591.75 - 438.68 X$
5.	Crude fibre content (%)	$r = 0.6712$	•	$\hat{Y} = -2953.83 + 510.25 X$
6.	Bitter principles (%)	$r = -0.3473$	—	$\hat{Y} = 2574.65 - 65.25 X$
7.	Starch content (%)	$r = -0.8012$	••	$\hat{Y} = 8406.25 - 736.72 X$
8.	Specific gravity	$r = -0.7956$	••	$\hat{Y} = 834614 - 84703.10 X$
9.	Leaf protein (%)	$r = 0.2536$	—	$\hat{Y} = -1267.25 + 12676.78 X$
10.	Root protein (%)	$r = 0.1664$	—	$\hat{Y} = 2141.44 + 49.58 X$
IV Enzyme activity				
1.	Leaf IAA oxidase	$r = 0.8168$	••	$\hat{Y} = 10311.66 + 47.76 X$
2.	Root „ „	$r = 0.6004$	•	$\hat{Y} = 2788.26 + 42.29 X$
3.	Leaf peroxidase	$r = 0.4547$	—	$\hat{Y} = -2326.04 + 16884831 X$
4.	Root „ „	$r = 0.7023$	••	$\hat{Y} = -6550.75 + 202133.66 X$
5.	Leaf catalase	$r = 0.3838$	—	$\hat{Y} = -2524.00 + 10906.67 X$
6.	Root „ „	$r = 0.7477$	••	$\hat{Y} = -2490.48 + 14861.34 X$
V Endogenous hormonal changes				
1.	Leaf auxin (µg/g)	$r = 0.9218$	••	$\hat{Y} = 4521.42 - 1186.80 X$
2.	Root „ „	$r = 0.9043$	••	$\hat{Y} = 4933.84 - 1209.74 X$
3.	Leaf gibberellin (µg/g)	$r = 0.6457$	•	$\hat{Y} = -14.09 + 151.58 X$
4.	Root „ „	$r = 0.5765$	•	$\hat{Y} = 166.62 + 149.68 X$
5.	Leaf cytokinin „	$r = -0.5837$	•	$\hat{Y} = 4976.37 - 11005.69 X$
6.	Root „ „	$r = -0.5876$	•	$\hat{Y} = 5052.92 - 11335.33 X$
7.	Leaf ABA (µg/g)	$r = 0.2617$	—	$\hat{Y} = 1310.26 + 635.38 X$
8.	Root „ „	$r = 0.3403$	—	$\hat{Y} = 1120.65 + 724.55 X$

P (0.05%) = 0.576

P (0.01%) = 0.708

4:1:6 CORRELATION STUDIES

Simple correlation functions with regression equation were computed to assess the degree of relationship between the photothermal unit on one hand and yield components on the other (Table 29).

4:1:6:1 Effect of photothermal unit on growth and yield

Of the several components, length of the root, girth of the root, fresh weight of the tops, dry weight of tops, dry weight of roots and Net Assimilation Rate (NAR) had a negative and highly significant correlation with photothermal unit, their values being $r = -0.7333$, -0.7951 , -0.7239 , -0.7214 , -0.7151 and -0.7177 . The mean root weight and total fresh weight of the roots also had a negative correlation with less significance ($r = -0.6056$, -0.6803). Among all the parameters studied, only the number of bolted plants had a positive and highly significant correlation with the photothermal unit ($r = 0.8194$). The relationship between the relative growth rate and photothermal unit was not discernible. There was no influences of PTU on number of leaves, leaf area, harvest index and RGR.

4:1:6:2 Effect of photothermal unit on nutrients

Nitrogen content in the leaves, phosphorous content in the root and leaf potassium had a negative correlation with photothermal unit, the values being $r = -0.7141$, -0.6109 and -0.6653 respectively. There was no relationship with the other components.

4:1:6:3 Photothermal unit on quality attributes

Among the quality components, starch content and crude fibre content showed a high positive relationship with photothermal unit ($r = 0.8012$, $r = 0.6712$). Other quality attributes such as reducing sugar, specific gravity of the infusion had a high negative correlation ($r = -0.9516$, -0.7596). No relationship was perceptible in other quality attributes such as total sugar, non-reducing sugar, bitter principles and protein content in the leaves and roots.

4:1:6:4 Photothermal unit on enzyme activity

IAA oxidase activity in leaves and roots, peroxidase and catalase activity in the roots exhibited a positive and significant correlation with photothermal unit ($r = 0.8316$, 0.6004 , 0.7203 , 0.7477) and no relationship was seen on leaf peroxidase and leaf catalase activities.

4:1:6:5 Photothermal unit on endogenous hormones

The auxin and gibberellin content both in the leaves and roots showed a positive correlation, the values being $r = 0.9218$, 0.9450 , 0.6457 and 0.5765 and among them, the relationship was stronger in the case of auxin than in the case of gibberellin. The cytokinin content registered a negative relationship with PTU ($r = -0.5837$, -0.5876). There was no relationship with ABA content in the leaves and roots.

4:2 STAGES OF HARVEST

In order to obtain an idea of the factors influencing the quality of tubers, studies on stages of harvest were conducted and the results are presented below :

4:2:1 Growth attributes

The mean number of leaves produced by the plant, leaf area, length and girth of the roots, mean weight of the roots and girth/length ratio were recorded and the data are presented in Table 30; Fig.13, 14) .

4:2:1:1 Number of leaves

The increase in the production of leaves from 105th to 120th day was markedly and significantly high (24.6 to 37.2) . After 120 days, the production of leaves seemed to be static and ranged within narrow limits (37.2 - 38.4) .

4:2:1:2 Leaf area

The leaf area was the highest 135 days after sowing (43.96 dm^2) . There was a small reduction in the leaf area subsequent to 135 days. The greatest increase in leaf area from 26.36 dm^2 to 42.72 dm^2 was noted between 90 and 120 days after sowing.

4:2:1:3 Length of roots

The length of the roots showed a progressively increasing trend from 3.2 cm on the 30th day and attained

Table 30 EFFECT OF STAGES OF HARVEST ON MEAN NUMBER
OF LEAVES, LEAF AREA, LENGTH, GIRTH
OF THE ROOT, GIRTH/LENGTH RATIO
AND MEAN WEIGHT OF A ROOT

S.No.	Days after sowing	Mean number of leaves	Leaf area (dm ²)	Length of the root (cm)	Girth of the root (cm)	Girth/length ratio	Mean weight of root (g)
1.	30	3.6	4.39	5.2	0.9	0.17	1.4
2.	45	6.3	7.43	10.4	2.3	0.26	3.2
3.	60	8.5	11.33	15.6	4.2	0.27	12.7
4.	75	16.2	19.40	17.8	5.3	0.29	45.3
5.	90	22.4	26.36	18.6	11.4	0.61	95.4
6.	105	24.6	28.61	32.4	22.8	0.70	106.8
7.	120	37.2	42.72	47.6	29.3	0.61	149.2
8.	135	38.4	43.96	47.9	29.7	0.62	149.9
9.	150	38.2	42.82	46.5	29.9	0.64	152.2
10.	165	38.0	41.95	46.3	29.8	0.64	150.9
11.	180	37.8	40.43	46.1	29.0	0.62	150.8
	S.E.	1.782	1.394	3.231	1.692	-	6.321
	C.D. (p=0.05)	5.245	4.382	9.876	5.077	-	18.971

FIG.13 EFFECT OF STAGES OF HARVEST ON LEAF AREA, LENGTH AND GIRTH OF THE ROOT, LENGTH/GIRTH RATIO AND MEAN WEIGHT OF THE ROOT

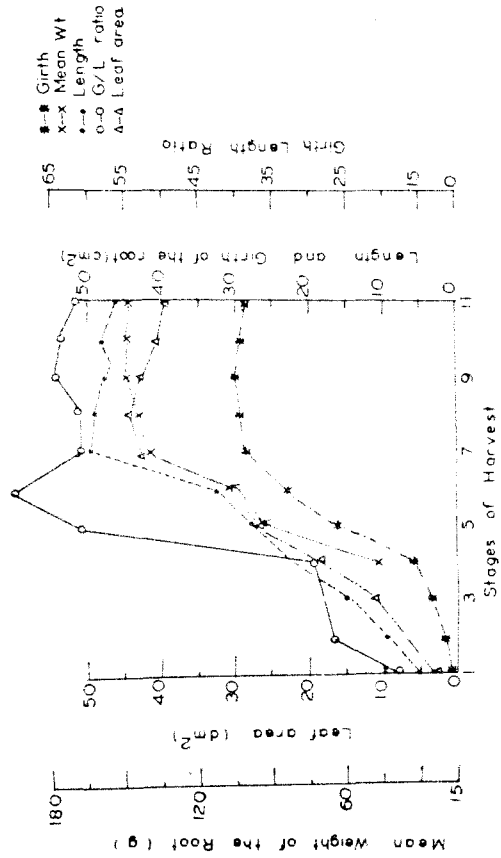


FIG.13 EFFECT OF STAGES OF HARVEST ON LEAF AREA, LENGTH AND GIRTH OF THE ROOT, LENGTH/GIRTH RATIO AND MEAN WEIGHT OF THE ROOT

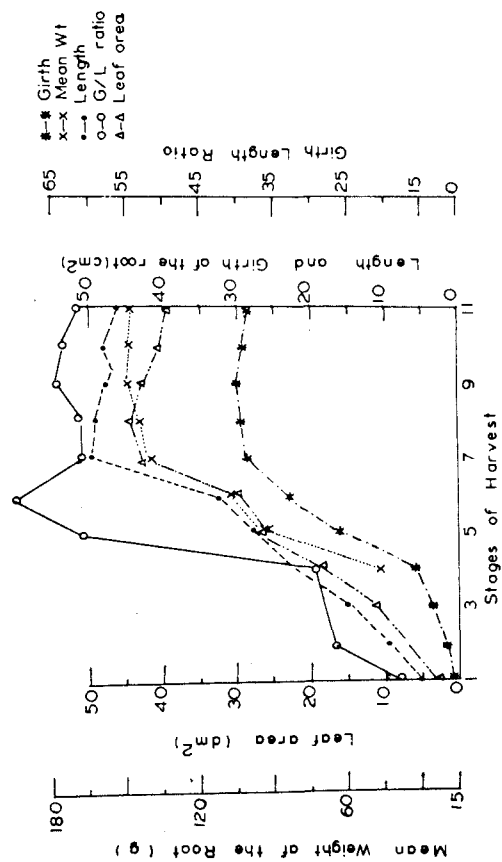
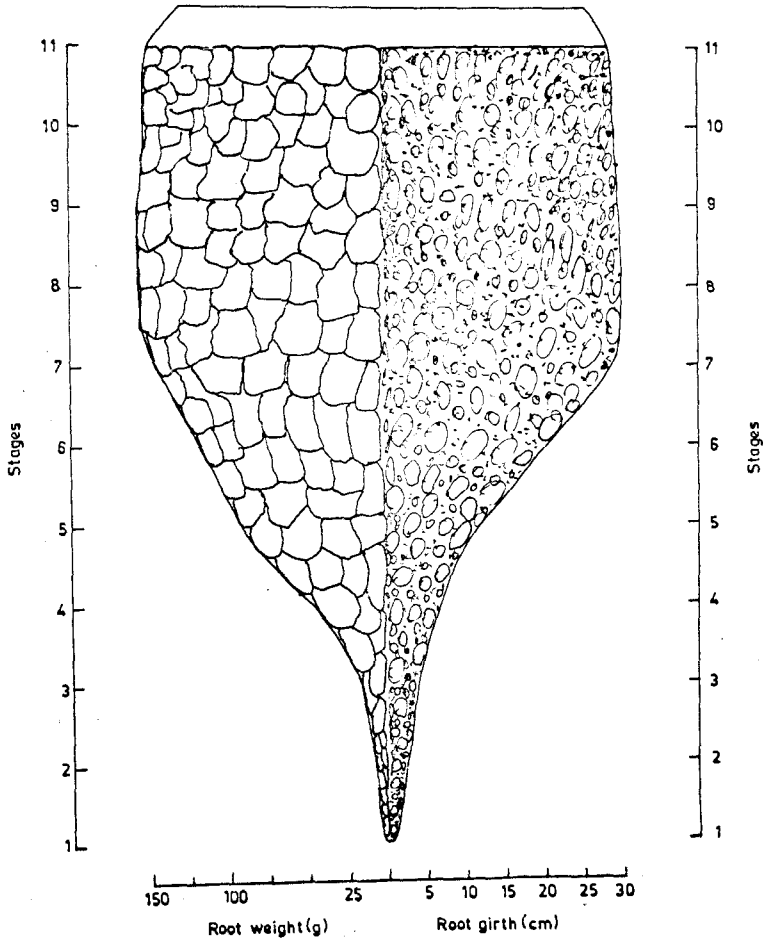


Fig.14. Effect of stages of harvest on root girth (cm) and root weight(g)



the highest value (47.9 cm) on the 135th day. The increase between 120 and 180 was narrow from 46.1 to 47.6 cm. A sharp increase from 18.6 to 32.4 cm was noted between 90 and 105 days after sowing. The stage of harvest had significant influence on this character.

4:2:1:4 Girth of the root

Root girth progressively increased from the 30th day (0.9 cm) to 150th day (29.9 cm) and at that stage it attained the highest value. Thereafter there was a slight decline. The increase in girth was remarkably faster between 90 (11.4 cm) and 105 days (22.8 cm) after sowing.

4:2:1:5 Girth/length ratio

The greatest girth/length ratio was obtained after 105 days (0.70) followed by 150th and 165th days (0.64). The ratio on the 90th day and 125th day was 0.61. In the early stages the ratio was very low, ranging from 0.17 to 0.29 from 30 to 75 days.

4:2:1:6 Weight of the root (g)

The highest mean weight of root (152.28 g) was recorded at 150 days, followed by 165th day and 180th day (150.9 g, 150.8 g). The mean weight of roots varied within narrow limits beyond 120th day. The increase in tuber weight was perceptibly greater from the 75th day to 105th day (45.3 and 95.4 g).

4:2:2 Effect of stage of harvest on the fresh weight of tops, fresh weight of the roots and top/root ratio

The fresh weight of the tops and roots were recorded at each stage and top/root ratio was calculated. The results are presented in Table 31.

4:2:2:1 Fresh weight of tops

The fresh weight of tops increased progressively from the initial stage (30th day) and attained the highest value at 120th day (29,175 kg/ha). Thereafter, a decrease in the fresh weight of top was observed but the differences recorded between 135th day to 180th day were narrow. Though a steady rise in the weight of tops was observed in the initial stages, a sharp increase was noted from 75 to 90 days (18,175 to 22,390 kg/ha). Highly significant differences were noted among the different stages of harvest.

4:2:2:2 Fresh weight of the roots

The highest fresh weight of roots was recorded at the 120th day of harvest (25,975 kg/ha) but less root fresh weight was recorded in the subsequent stages of harvest. The fresh root weights recorded on 120th, 135th and 150th day were on par. In the initial stage, there was a steady increase in the root yield but the increase was very marked after 75 days. Highly significant differences were noticed among the different stages of harvest.

Table 31 **EFFECT OF STAGES OF HARVEST ON FRESH
WEIGHT OF TOPS, ROOTS AND TOP/SHOOT
RATIO**

S.No.	Days after sowing	Fresh weight of tops (Kg/ha)	Fresh weight of roots (kg/ha)	Top/ shoot ratio
1.	30	195	86	2.26
2.	45	5085	2090	2.86
3.	60	8409	5853	1.43
4.	75	18175	12932	1.40
5.	90	22390	20340	1.10
6.	105	27140	22119	1.12
7.	120	29175	25975	1.13
8.	135	28680	25817	1.10
9.	150	28530	25819	1.11
10.	165	28515	25615	1.12
11.	180	28310	25015	1.32
	S.E.	165.2	108.25	
	C.S. (P=0.05)	495.6	324.75	

4:2:2:3 Top/root ratio

The top/root ratio was high in the early stages of harvest on the 30th and 45th day (2.26 and 2.86) and thereafter the ratios declined. The least ratio was obtained on the 90th and 120th day (1.10). Though the ratios beyond 120th day were found to be decreasing, at the last stage (180 days) a slight increase was observed.

The dry weight of the tops and roots were recorded in all the stages of harvest. From the dry weights harvest index was calculated and the results are furnished in Table 32.

4:2:2:4 Dry weight of the tops

The dry weight of the tops was the highest on the 120th day of harvest (9,590 kg/ha) and thereafter there was a declining trend in the subsequent stages. From the 90th day to 120th day the increase was of the highest magnitude (5,840 kg/ha to 9,590 kg/ha).

4:2:2:5 Dry weight of the roots

The trend of increase in the dry weight of roots was similar to that of the dry weight of tops. The crop harvested on the 120th day registered a high dry weight of 8,870 kg/ha closely followed by 135th day (8,019 kg/ha). Delayed harvest beyond 135th days resulted in a decrease in the dry weight of roots.

Table 32 EFFECT OF STAGES OF HARVEST ON DRY WEIGHT
OF TOPS, DRY WEIGHT OF ROOTS AND
HARVEST INDEX

S.No.	Days after sowing	Dry weight of the tops (kg/ha)	Dry weight of the roots (kg/ha)	Harvest index
1.	30	64	55	46.21
2.	45	1085	870	44.50
3.	60	2175	1985	46.71
4.	75	4015	3075	43.37
5.	90	5840	4481	43.41
6.	105	7690	6950	47.46
7.	120	9590	8870	48.05
8.	135	8745	8019	47.83
9.	150	8630	7950	47.94
10.	165	8317	7818	48.45
11.	180	9015	7780	49.25
	S.E.	102.82	72.624	
	CD (P=0.05)	308.46	217.872	

4:2:2:6 Harvest index

The harvest index ranged from 43.46 to 49.43. The highest harvest index was recorded at the 180th day harvest (49.23), followed by 163th day (48.43) and 120th day (48.05). The differences among the stages of harvest were not substantial. In the initial stages except the 30th and 60th day at all other stages the harvest index was lower till the 105th day when it had a markedly higher value (47.46) and thereafter, it ranged narrowly between 47.83 and 49.25.

The net assimilation rate and relative growth rate were worked out and furnished in Table 33.

4:2:2:7 Net Assimilation Rate (NAR)

The net assimilation rate was seen to increase progressively upto 120th day when the highest value was recorded. Thereafter, there was a gradual decline.

4:2:2:8 Relative Growth Rate (RGR)

The relative growth rate followed the same trend as NAR. The highest RGR was recorded on the 120th day (0.262).

4:2:3 Nutrients

The nutrients such as nitrogen, phosphorus and potassium in the leaves and roots were analysed and the data are furnished in Table 34.

Table 33 EFFECT OF STAGES OF HARVEST ON NET
ASSIMILATION RATE AND RELATIVE
GROWTH RATE

S.No.	Days after Sowing	N A ₂ R (mg/dm ² /day)	R G R (mg/g/day)
1.	30	0.234	0.072
2.	45	0.348	0.084
3.	60	0.942	0.162
4.	75	1.043	0.184
5.	90	1.635	0.214
6.	105	1.678	0.219
7.	120	1.924	0.262
8.	135	1.829	0.247
9.	150	1.823	0.244
10.	165	1.817	0.243
11.	180	1.806	0.241
	S.E.	0.068	0.062
	CD (P=0.05)	0.204	0.186

Table 34 EFFECT OF STAGES OF HARVEST ON NITROGEN,
PHOSPHORUS AND POTASSIUM CONTENT(PERCENT)

S.No.	Days after sowing	Nitrogen		Phosphorus		Potassium	
		Leaves	Roots	Leaves	Roots	Leaves	Roots
1.	30	1.152	1.029	0.118	0.109	2.05	3.09
2.	45	1.152	1.030	0.115	0.098	2.55	3.06
3.	60	1.167	1.134	0.099	0.093	3.70	3.94
4.	75	1.136	1.122	0.093	0.087	3.75	3.93
5.	90	1.062	1.049	0.064	0.061	3.79	3.84
6.	105	1.004	1.040	0.062	0.059	3.64	3.72
7.	120	0.983	0.943	0.059	0.055	3.52	3.66
8.	135	0.996	0.941	0.058	0.051	3.50	3.49
9.	150	0.964	0.889	0.056	0.048	3.46	3.41
10.	165	0.948	0.883	0.049	0.043	3.42	3.36
11.	180	0.959	0.898	0.043	0.039	3.39	3.33
	S.E.	0.064	0.074	NS	NS	0.084	0.052
	CD (P=0.05)	0.192	0.222			0.252	0.156

4:2:3:1 Nitrogen

In the leaves, the nitrogen content was found to be high in the early stages of harvest and the highest value was noted on the 60th day (1.163%), followed by 30th and 45th days (1.152%). From the 60th day, nitrogen content decreased as the stage of harvest was delayed and a low nitrogen content was recorded in the crop harvested on the 165th day (0.948%). The root nitrogen content also followed the same trend. A high nitrogen content was recorded on the 60th day (1.134%) and declined thereafter. The lowest nitrogen content was noted in the last stage of harvest (0.878%). The differences were significant.

4:2:3:2 Phosphorus content

The phosphorus content in leaves and roots at different stages of harvest did not vary significantly. But in the early stages of harvest the leaf phosphorus content was high and a declining trend was seen in the subsequent stages of harvest. The least value was noted on the 180th day harvest (0.043%). The root phosphorus content was lower than in leaf and the values at the different stages of harvest followed the same pattern as the leaf phosphorus content.

4:2:3:3 Potassium content

Contrary to the trend noted in N and P, a significant increase in leaf K content was noted upto the 90th day when the highest value (3.79%) was recorded. Later, it declined and the lowest value was recorded on the 180th day, but the decrease in the later stages from 120th day to 180th day was not steep and the values differed only narrowly. In the roots the potassium content was high on the 60th day (3.94%) and thereafter its content declined to the lowest value of 3.33% on the 180th day.

4:2:4 Quality of roots

Quality attributes such as starch granules accumulation, starch per cent, crude fibre content, bitter principles, sugars and its fractions, protein per cent, aminoacids and its fractions and infusions which have an influence on the quality of the roots were studied with reference to the stages of harvest and are presented below :

4:2:4:1 Starch granules accumulation

The mean number of starch granules accumulation in the top, middle and bottom portion of the roots were calculated (Table 35).

In the top portion of the roots, starch granules accumulation was high on the 135th day harvest (172.7), closely followed by 150th day (169.8) and 120th day (168.3) which were on par. Starch granules accumulation was

Table 35 EFFECT OF STAGES OF HARVEST ON
STARCH GRANULES ACCUMULATION

S.No.	Days after sowing	<u>Mean number of starch granules per field</u>		
		<u>Top of the root</u>	<u>Middle portion</u>	<u>Bottom portion</u>
1.	30	-	-	-
2.	45	5.2	7.6	9.4
3.	60	82.4	88.9	92.7
4.	75	96.3	92.7	98.6
5.	90	126.5	102.3	143.5
6.	105	154.9	141.1	165.9
7.	120	168.3	166.4	193.3
8.	135	172.7	168.3	194.2
9.	150	169.8	165.6	192.1
10.	165	165.3	162.2	190.8
11.	180	163.1	161.4	187.3
	S.E.	8.02	7.74	5.49
	CD (P=0.05)	24.06	23.22	16.47

initiated only on the 45th day after sowing and its content increased upto 135th day and thereafter declined on the 180th day (163.1). A high starch granules accumulation in the middle portion was observed on the 135th day (168.3), followed by 120th day (166.4) and 150th day (165.6) which were on par. Here also in the initial stage, the starch accumulation was little and increased progressively and attained the highest value on the 135th day of harvest. In the bottom portion of the root, the starch accumulation was again high on the 135th day (194.2). The content in this part of the root was slightly higher than the middle and top portions. As the stage of harvest was delayed the starch granules accumulation also decreased.

The starch per cent, crude fibre content and bitter principles were analysed and furnished in Table 36.

4:2:4:3 Starch content

The starch content was noted only on the 45th day and later it increased significantly and progressively reaching the highest value on the 165th day after sowing (10.81%). The increase in the starch content from the 75th to 120th day was remarkable (from 6.21% to 10.24%).

4:2:4:4 Crude fibre content

The crude fibre content was high on the 120th day harvest (13.2%) and there was a gradual decrease in the

Table 36 EFFECT OF STAGES OF HARVEST ON STARCH
CONTENT, CRUDE FIBRE CONTENT AND
BITTER PRINCIPLES

S.No.	Days after sowing	Starch (%)	Crude fibre (%)	Bitter principles (%)	
				Leaves	Roots
1.	30	-	2.1	4.2	2.1
2.	45	2.47	2.3	4.3	2.7
3.	60	3.72	4.7	4.9	4.7
4.	75	4.86	4.9	5.2	7.4
5.	90	5.38	6.8	5.1	7.6
6.	105	6.21	7.2	5.0	7.3
7.	120	10.24	8.6	4.8	8.6
8.	135	10.32	12.1	4.7	9.2
9.	150	10.80	10.3	4.5	6.9
10.	165	10.81	10.2	4.3	6.6
11.	180	10.60	10.0	4.2	4.9
S.E.		0.1204	0.0673	0.162	0.0995
cd (P=0.05)		0.3612	0.2019	0.486	0.3085

subsequent stages of harvest. In the early stages, its content was very low. The increase from 105th to 120th day was conspicuous and significant.

4:2:4:5 Bitter principles

In the leaves, a high percentage of bitter principle was recorded on the 75th day harvest (5.2%) which was closely followed by 90th day (5.1%) and declined thereafter. On the 120th day, its content was 4.8 per cent. The differences in the bitter principles content among the stages of harvest was significant. In the roots, its content was high on the 135th day harvest (9.2%), followed by 120th day (8.6%) and 90th day (7.6%). Thereafter, there was declining trend as the harvest was delayed. When compared to leaves, in general, roots were found to contain a greater quantity of bitter principles.

The reducing sugars, non-reducing sugars and total sugars were analysed and expressed as per cent. Significant influences due to stage of harvest was noticed in each case. The results are presented in Table 37; Fig. 15.

4:2:4:6 Reducing Sugars

The reducing sugar content was high on the 150th day (4.24%) which was closely followed by 135th day and 165th day (4.16% and 4.17%). Reducing sugars was absent on the 30th and 45th days and were much less till the 75th day.

Table 37 **EFFECT OF STAGES OF HARVEST ON REDUCING
SUGARS, NON REDUCING SUGARS AND TOTAL
SUGARS OF CHICORY ROOT (PERCENT ON DRY
WEIGHT BASIS)**

S.No.	Days after sowing	Reducing sugars	Non reducing sugars	Total sugars
1.	30	-	-	-
2.	45	-	-	-
3.	60	2.13	3.17	5.30
4.	75	3.06	3.85	6.91
5.	90	3.72	4.10	7.82
6.	105	4.05	4.62	8.67
7.	120	4.14	4.85	8.99
8.	135	4.16	4.92	9.08
9.	150	4.24	4.65	8.89
10.	165	4.17	4.62	8.79
11.	180	4.05	4.15	8.20
	S.E.	0.06	0.04	0.06
	CD (P=0.05)	0.13	0.12	0.18

Fig.15 Effect of stages of harvest on reducing sugar and non-reducing sugar

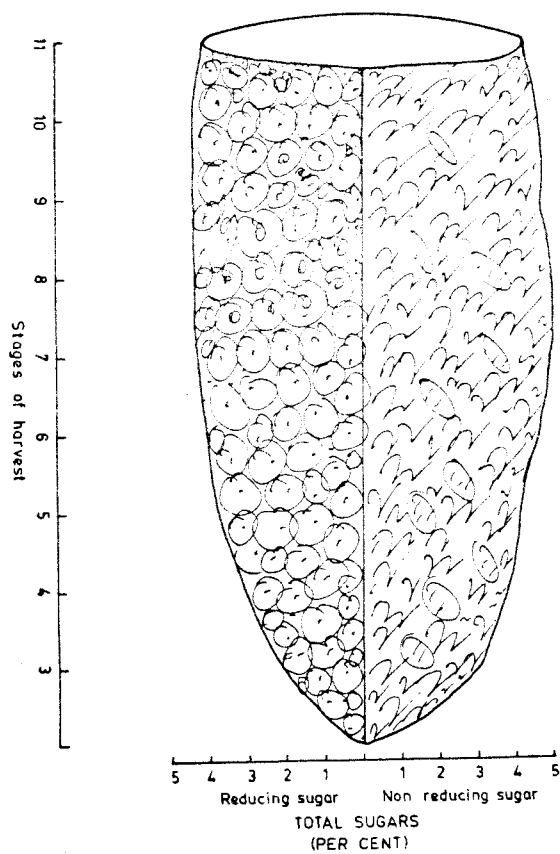
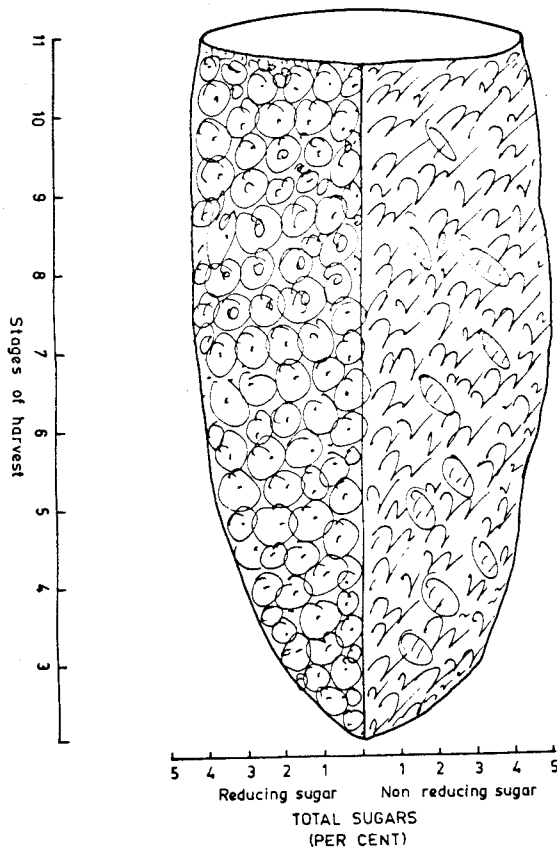


Fig.15 Effect of stages of harvest on reducing sugar and non-reducing sugar



4:2:4:7 Non-reducing sugars

Roots harvested at 135th day had a high non-reducing sugar content (4.92%), followed by those harvested on the 120th day (4.85%). The non-reducing sugar content in the later stages of harvest was less than at the 135th day.

4:2:4:8 Total sugars

The total sugar content also followed the same trend as the reducing and non-reducing sugars. A high total sugar content was recorded on 135th day (9.08%) and 120th day (8.99%). Beyond 135th day the values were less. There was a progressively increasing trend from the 60th day onward till the 135th day.

The reducing sugar content on fresh weight basis and its fractions such as fructose and glucose were assayed (Table 38).

4:2:4:9 Reducing sugars

The reducing sugar content at various stages of harvest showed significant differences. The highest value was noted on the 120th day harvest (18.5%), which was closely followed by 135th day (18.1%) and a declining trend was noticed thereafter. In the initial stages, reducing sugar content was low on the 60th day (2.1%) and rose to 14.7% in 105th day of harvest.

Table 38 EFFECT OF STAGES OF HARVEST IN REDUCING SUGARS, GLUCOSE AND FRUCTOSE CONTENT IN CHICORY ROOT ON FRESH WEIGHT BASIS

S.No.	Days after sowing	Reducing sugars (%)	Fructose* (%)	Glucose* (%)
1.	30	-	-	-
2.	45	-	-	-
3.	60	2.1	80.1	19.9
4.	75	4.8	80.2	19.8
5.	90	12.0	81.3	18.7
6.	105	14.7	82.8	17.2
7.	120	18.5	83.7	16.3
8.	135	18.1	81.5	18.5
9.	150	16.1	80.5	19.5
10.	165	14.0	80.2	19.8
11.	180	14.0	80.3	19.7
	S.E.	0.082	NS	NS
	CD (P=0.05)	0.247	-	-

* Concentration expressed as a percentage of total reducing sugars.

4:2:4:10 Fructose (per cent)

The percentage of fructose in the reducing sugars was high on the 120th day (83.7), followed by the 105th day (82.7%) whereas it was low in the 30th day (80.1%). The values differed narrowly.

4:2:4:11 Glucose (per cent)

In the initial stages of the crop, the glucose content was high on the 60th day (19.9%) and on the 75th day (19.8%), but showed an inconsistent trend after 120 days. The lowest value (16.3%) was recorded on the 120th day.

The percentage of protein and total amino acids were analysed and the values was found to show significant differences among the stages of harvest (Table 39).

4:2:4:12 Protein (per cent)

In the leaves, the percentage of protein was high on the 165th day (2.03%) which was closely followed by 150th day (2.02%) and 135th day (2.01%). A moderate quantum of protein content was recorded on the 120th day (1.88%). In the initial stages of harvest, the protein content was very low ranging between 1.23 and 1.36%. In the roots, the percentage of protein was high on the 120th day (5.67%) which was closely followed by 105th day (5.52%) and 135th day (5.41%). In the later stages, protein content was reduced

Table 39 EFFECT OF STAGES OF HARVEST ON PROTEIN
CONTENT AND TOTAL AMINO ACID CONTENT

S.No.	Days after sowing	Protein(per cent)		Aminoacids(μ g/g)	
		Leaves	Roots	Leaves	Roots
1.	30	1.23	3.41	1901.6	3103.3
2.	45	1.27	3.63	1914.6	3500.6
3.	60	1.30	3.92	1946.3	3385.6
4.	75	1.30	4.13	2012.3	3395.6
5.	90	1.34	5.21	2065.6	3409.3
6.	105	1.36	5.52	2096.3	3407.0
7.	120	1.88	5.67	2299.0	4185.6
8.	135	2.01	5.41	2007.3	4070.6
9.	150	2.02	5.40	1986.3	3680.6
10.	165	2.03	5.38	1011.3	3553.3
11.	180	1.99	5.37	1812.0	3013.0
	S.E.	0.009	0.028	7.692	15.04
	CD (P=0.05)	0.026	0.084	23.076	45.12

as the harvest was delayed. The protein content increased with delay in harvest stage (from 3.41% on 30th day to 5.21% on 90th day of harvest).

4:2:4:13 Total amino acids

The leaf amino acids content was high on the 120th day harvest (2,299.0 $\mu\text{g/g}$). It increased from the 30th day of harvest (1,901.6 $\mu\text{g/g}$) till the 120th day of harvest, after which, there was a steady reduction and it was very low on the 165th day harvest (1,811.3 $\mu\text{g/g}$). In the roots, total amino acids content was high on the 120th day harvest (4,185.6 $\mu\text{g/g}$) which was closely followed by 135th day (4,070.6 $\mu\text{g/g}$). The total amino acids content was very low beyond 135th day.

4:2:4:14 Aminoacids content on the 75th, 120th and 180th days

The different aminoacids in leaves and roots were assayed at three stages (Table 40). On the 75th day, in the leaves the content of amino acid, arginine was high (380.0 $\mu\text{g/g}$) but the content of alanine was low (90.0 $\mu\text{g/g}$). In the roots, serine, dihydroxy phenylalanine, lysine, histidine, theanine, proline, glutamic acid and glycine were present in appreciable quantities. Of these, histidine content was found to be high (604.6 $\mu\text{g/g}$). In the roots, alanine was not present but proline, glutamic acid and glycine were present, but were absent in the leaves.

Table 40 AMINO ACIDS CONTENTS ON 75th, 120th AND 180th
DAY OF HARVEST

S.No.	Name of the amino acids	Amino acids content($\mu\text{g/g}$)	
		Leaves	Roots
<u>75th day</u>			
1.	Arginine	380.0	-
2.	Serine	279.3	468.0
3.	Dihydroxy phenyalanine	401.3	467.5
4.	Lysine	315.6	535.0
5.	Histidine	329.3	604.6
6.	Theorine	295.3	542.6
7.	Alanine	90.0	-
8.	Proline	-	476.3
9.	Glutamic acid	-	540.3
10.	Glycine	-	454.6
<u>120th day</u>			
1.	Proline	593.6	-
2.	Serine	592.6	368.3
3.	Glutamic acid	518.0	279.0
4.	Arginine	386.3	-
5.	Cystine	551.0	533.3
6.	Valaine	637.6	-
7.	Lysine	620.6	-
8.	Alanine	-	27.0
9.	Tyrosine	-	336.6
10.	Histidine	-	553.0
11.	Arginine	-	356.6
<u>180th day</u>			
1.	Tyrosine	210.0	104.3
2.	Cystine	258.3	93.3
3.	Histidine	347.3	126.6
4.	Valine	516.6	-
5.	Proline	318.0	-
6.	Glutamic acid	284.0	-
7.	Serine	-	73.0
8.	Arginine	-	87.6

In the leaves on the 120th day, proline, serine, glutamic acid, arginine, cystine, valine and lysine were present. The individual content of these amino acids was fairly higher than at the 75th day. In the roots, serine, glutamic acid, cystine, alanine, tyrosine, histidine and arginine were present. Among these, amino acid histidine showed a high value (553 $\mu\text{g/g}$) and cystine content was also appreciable (533.3 $\mu\text{g/g}$).

At 180th day stage, the amino acids such as tyrosine, cystine, histidine, valine, proline and glutamic acid were found in the leaves. Among them valine content was high (516.6 $\mu\text{g/g}$). In the roots, tyrosine, cystine, histidine, serine and arginine were present and histidine content was high (126.6 $\mu\text{g/g}$). In general, amino acids content was very low both in the leaves and roots at this stage when compared to the previous stages of harvest.

4:2:4:15 Specific gravity of the infusion

The specific gravity of the chicory infusion was high in roots harvested on the 120th day (1.0237), which was closely followed by 135th day (1.0224) and 105th day (1.0225). The specific gravity was very low in the early harvests but increased when the roots were harvested after 105 days (Table 41).

Table 41. EFFECT OF STAGES OF HARVEST ON THE SPECIFIC GRAVITY OF THE CHICORY ROOT INFUSION

S.No.	Days after sowing	Specific gravity *
1.	30	1.0065
2.	45	1.0070
3.	60	1.0082
4.	75	1.0090
5.	90	1.0190
6.	105	1.0225
7.	120	1.0237
8.	135	1.0224
9.	150	1.0217
10.	165	1.0204
11.	180	1.0192

* The Specific gravity of coffee bean infusion was 1.0080.

4:2:5 ENZYME ACTIVITY

The IAA oxidase, peroxidase and catalase activity was estimated in the leaves and roots showed significant differences were noted among the stages of harvest (Table 42).

4:2:5:1 IAA oxidase

High IAA oxidase activity was observed on the 60th day (283) in the leaves, which was closely followed by 45th day (281) and 30th day (279). After the 60th day, there was a sharp reduction in its activity in the subsequent harvests and the least content was recorded in the crop harvested on the 180th day. In the roots, IAA oxidase activity was very high in the first stage itself (249.0), which was closely followed by 45th day (242) and 60th day (241.3). Then there was a reduction in the activity in the subsequent harvests. A low activity was seen in the crop harvested on the 180th day (210).

4:2:5:2 Peroxidase activity

In the leaves, the peroxidase activity was high on the 165th day (0.071), followed by 150th day (0.067) and 135th day (0.065). Its activity ranged between 0.052 in the first stage (30th day) to 0.071 in 165th day of harvest. A similar trend was noticed in the roots but the activity was high on the 180th day (0.063). In root in general, it was found to increase from the initial stage to the final stage.

Table 42 EFFECT OF STAGES OF HARVEST ON IAA OXIDASE, PEROXIDASE AND CATALASE ACTIVITY

S.No.	Days after sowing	IAA oxidase ($\mu\text{g}/\text{g}$ of IAA) oxidase per g per 2 hrs.		Peroxidase (difference in optical density per 10 minutes)		Catalase activity mg of hydrogen peroxide destroyed by catalase	
		Leaves	Roots	Leaves	Roots	Leaves	Roots
1.	30	279.0	249.0	0.052	0.037	0.426	0.613
2.	45	281.0	242.0	0.052	0.036	0.476	0.580
3.	60	283.0	241.3	0.058	0.037	0.516	0.576
4.	75	264.0	240.0	0.056	0.045	0.610	0.483
5.	90	249.0	234.0	0.059	0.046	0.750	0.483
6.	105	241.3	229.6	0.059	0.046	0.623	0.460
7.	120	241.0	239.3	0.061	0.047	0.610	0.433
8.	135	231.0	227.6	0.065	0.048	0.603	0.413
9.	150	221.6	228.0	0.067	0.051	0.513	0.410
10.	165	220.3	225.6	0.071	0.052	0.500	0.386
11.	180	218.0	210.0	0.050	0.053	0.486	0.370
S.E.		0.488	1.116	0.0016	0.0006	0.0050	0.0039
CD ($P=0.05$)		1.464	3.348	0.0048	0.0018	0.0148	0.0117

4:2:5:3 Catalase activity

In the leaves, the catalase activity was found to increase from the 30th day (0.426) and attained the highest value on the 90th day (0.750) and declined thereafter to the least value on the 180th day (0.486).

The catalase activity in the roots was high on the 30th day (0.613) and its content decreased progressively, the least activity being noted on the 180th day (0.370).

4:2:6 ENDOGENOUS HORMONAL CONTENT

Significant differences were noted among the stages in respect of endogenous content of auxin, gibberellin like substances, kinetin equivalent and ABA like substances.

4:2:6:1 Auxin content (Table 43; Fig.16)

High auxin content in the leaves was recorded on the 60th day (4.9 μ) and declined thereafter in the subsequent stages of harvest. The lowest auxin content was recorded on the 180th day harvest (3.5 μ). In the roots, auxin content was high on the 45th day and decreased thereafter and was the least on the 180th day (3.4 μ).

4:2:6:2 Gibberellin content (Table 43; Fig.16)

High gibberellin content was recorded on 180th day (5.8 μ g/g), followed by 165th day harvest (4.9 μ g/g). In the initial stages the gibberellin content was fairly

**Table 43. EFFECT OF STAGES OF HARVEST ON AUXIN CONTENT
OF LEAVES AND TUBERS (IAA EQUIVALENT $\mu\text{g/g}$)
AND GIBBERELLIN CONTENT ($\mu\text{g/g}$) ON FRESH
WEIGHT BASIS**

S.No.	Stages of harvest (days)	Auxin content (IAA equivalent) ($\mu\text{g/g}$)		Gibberellin content ($\mu\text{g/g}$)	
		Leaves	Roots	Leaves	Roots
1.	30	4.3	4.7	4.5	5.3
2.	45	4.6	4.9	4.3	5.0
3.	60	4.9	4.7	4.1	4.2
4.	75	4.5	4.4	4.0	4.1
5.	90	4.1	4.3	3.8	3.9
6.	105	4.0	4.3	3.8	3.7
7.	120	4.0	4.2	3.7	3.6
8.	135	3.9	4.0	3.9	3.8
9.	150	3.7	3.6	4.4	4.7
10.	165	3.7	3.5	4.9	5.7
11.	180	3.5	3.4	5.8	6.3

Fig.16 Effect of stages of harvest on auxin and gibberellin content

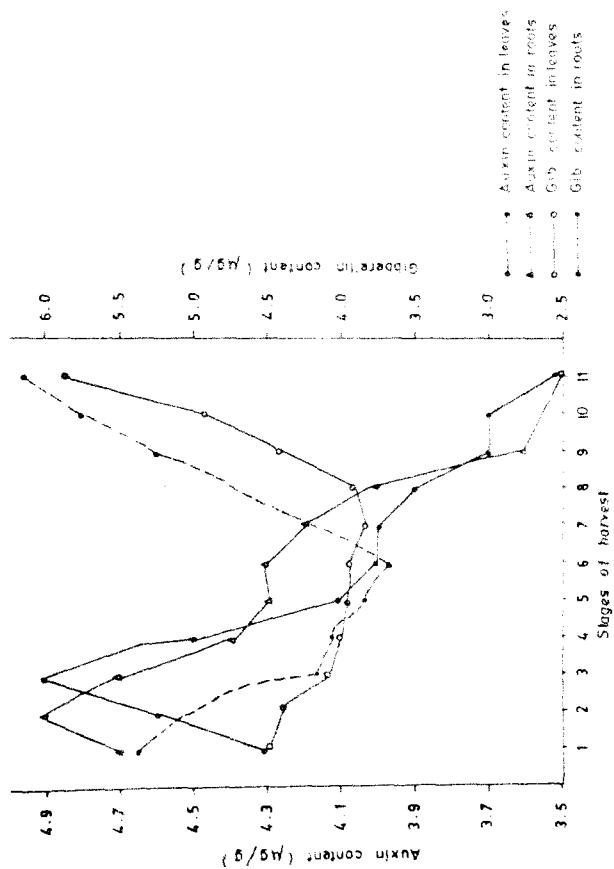
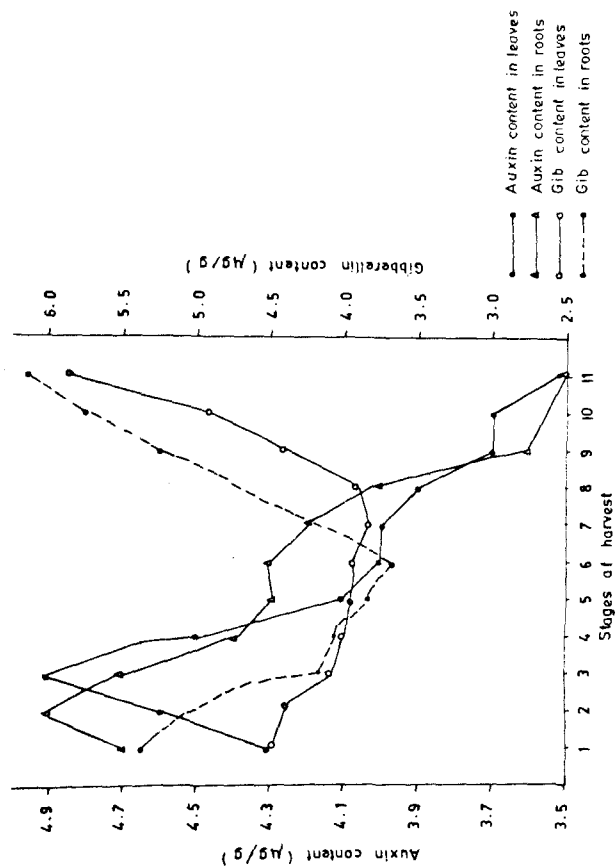


Fig.16 Effect of stages of harvest on auxin and gibberellin content



high, gradually declining to a low value of (3.7 μ g/g) on the 120th day. Subsequently there was an increase. The gibberellin content in the roots also followed a similar trend. High gibberellin content was recorded in the initial stages (5.3 μ g/g) and declined thereafter. The content was less on the 120th day (3.6 μ g/g) and increased subsequently till the 180th day (8.3 μ g/g).

4:2:6:3 CYTOKININ CONTENT (Table 44; Fig.17)

The cytokinin content in the leaves increased from the first stage (0.441 μ g/g) and attained the highest value on the 60th day (0.483 μ g/g). Later, the values declined and at the final stage its content was 0.231 μ g/g. In the roots, cytokinin content similarly increased from the initial stage (0.481 μ g/g) and attained a high value on the 120th day (0.499 μ g/g). A subsequent decrease to the lowest value at the final stage (0.342 μ g/g) was noted.

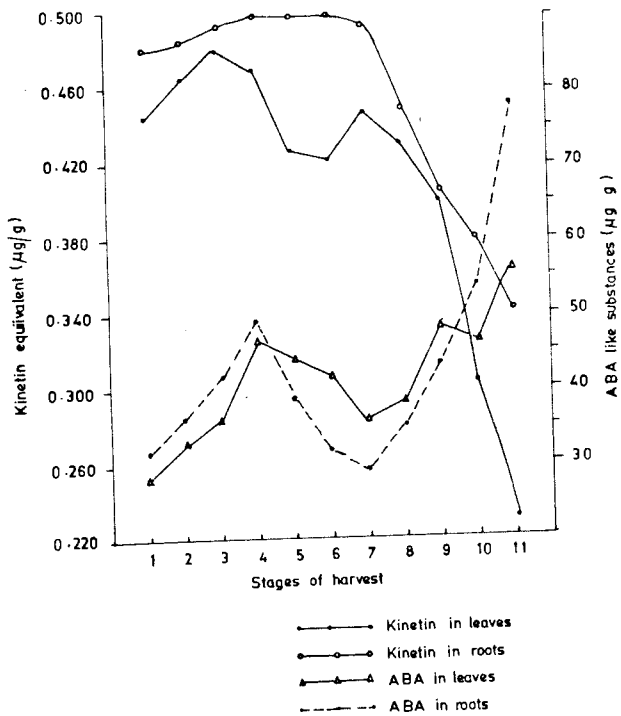
4:2:6:4 INHIBITOR CONTENT (Table 44; Fig.17)

The inhibitor content in the leaves was relatively higher in the final stages of harvest and was low in the initial stages. In between, a high value at 75th day, a declining values thereafter and a rise at 150th day were noted. A similar trend was noted in the roots also. A low content was noted on the 30th day (32 μ g/g) and it increased to 49 μ g/g on the 75th day. Thereafter it

Table 44 EFFECT OF STAGES OF HARVEST ON KINETIN
EQUIVALENT AND ABA LIKE SUBSTANCES (ug/g)
ON FRESH WEIGHT BASIS

S.No. of harvest	Stages	Kinetin equivalent (ug/g)		ABA like substances (ug/g)	
		Leaves	Roots	Leaves	Roots
1.	30	0.441	0.481	29	32
2.	45	0.462	0.489	33	36
3.	60	0.483	0.495	36	42
4.	75	0.471	0.496	47	49
5.	90	0.435	0.497	43	38
6.	105	0.432	0.497	42	32
7.	120	0.448	0.499	36	29
8.	135	0.431	0.491	39	35
9.	150	0.392	0.440	48	44
10.	165	0.392	0.402	46	52
11.	180	0.231	0.342	56	78

Fig.17 Effect of stages of harvest on Kinetin equivalent and ABA like substances



declined to 29 $\mu\text{g/g}$ on the 120th day and an upward increase was noted in the subsequent stages. At 180th day its content was 78 $\mu\text{g/g}$.

4:2:7 CORRELATION STUDIES

Simple correlation functions with regression equations were computed to assess the degree of influence of various attributes on yield (Table 45).

4:2:7:1 Growth

The growth components such as number of leaves, leaf area, length of the root, girth of the root and mean weight of the root had positive and highly significant correlation with yield; their values being $r = 0.9691$, 0.9754 , 0.9245 , 0.9384 and 0.9822 respectively.

4:2:7:2 Other attributes

The other attributes such as fresh weight of tops, dry weight of tops, dry weight of roots, NAR, RGR and harvest index also showed a positive and significant relationship with yield.

4:2:7:3 Nutrients

Leaf nitrogen and phosphorus contents ($r = -0.9388$ and $r = -0.9771$) showed negative relationship in the yield while leaf potassium content ($r = -0.6451$) had a positive correlation. Nitrogen and phosphorus content in the roots

Table 45 ASSOCIATION OF YIELD WITH GROWTH AND OTHER ATTRIBUTES

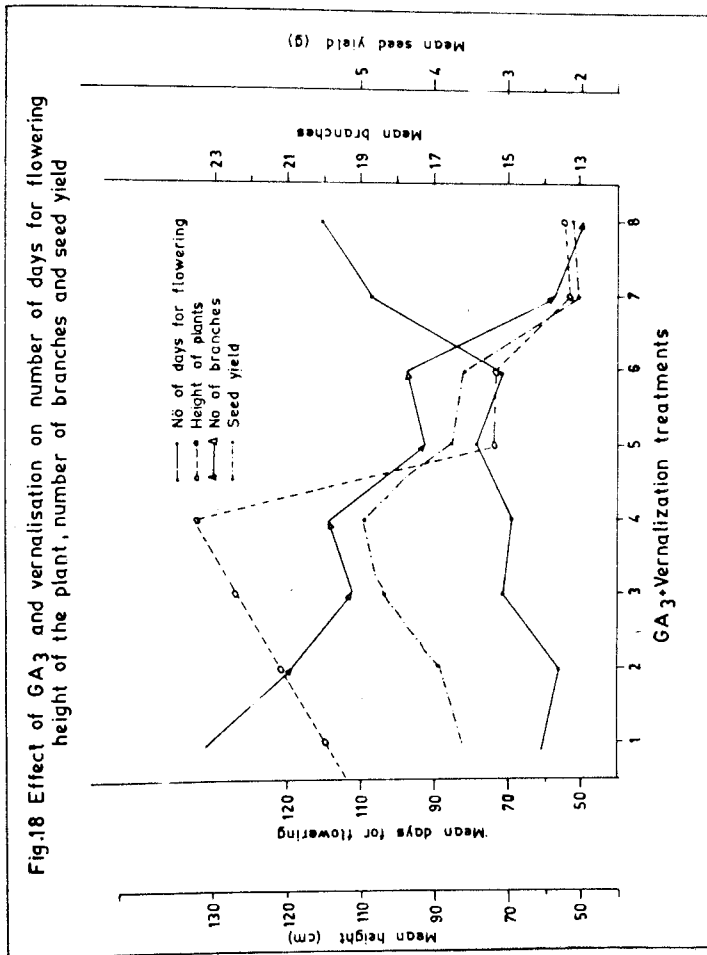
S.No	Character	Correlation coefficient (r)	Level of significance	Regression equation
I Growth				
1	Number of leaves	$r = 0.9691$	**	$\bar{Y} = 28.3 + 705.56 X$
2	Leaf area (dm^2)	$r = 0.9754$	**	$\bar{Y} = -896.90 + 651.34 X$
3	Root length (cm)	$r = 0.9245$	**	$\bar{Y} = 487.09 + 557.13 X$
4	Root girth (cm)	$r = 0.9384$	**	$\bar{Y} = 3913.24 + 761.34 X$
5	Mean weight of the root (g)	$r = 0.9822$	**	$\bar{Y} = 2989.06 + 155.91 X$
II Other yield attributes				
1	Fresh weight of tops (Kg/ha)	$r = 0.9312$	**	$\bar{Y} = -1776.33 + 0.94 X$
2	Dry weight of tops (Kg/ha)	$r = 0.9902$	**	$\bar{Y} = 75.51 + 2.973 X$
3	Dry weight of roots (Kg/ha)	$r = 0.9773$	**	$\bar{Y} = 1183.62 + 3.08 X$
4	Harvest index	$r = 0.8940$	*	$\bar{Y} = -178306.71 + 4185.84 X$
5	NAR	$r = 0.9858$	**	$\bar{Y} = -483.20 + 16238.95 X$
6	RGR	$r = 0.9714$	**	$\bar{Y} = -12490.77 + 151500.69 X$
III Nutrients				
1	Leaf nitrogen (%)	$r = -0.9388$	**	$\bar{Y} = 135881.65 - 11278.77 X$
2	Root nitrogen (%)	$r = -0.6847$	*	$\bar{Y} = 83047.28 - 78052.22 X$
3	Leaf phosphorus (%)	$r = -0.9771$	**	$\bar{Y} = 45953.08 - 373802.82 X$
4	Root phosphorus (%)	$r = -0.9722$	**	$\bar{Y} = 45973 - 407864.86 X$
5	Leaf potassium (%)	$r = 0.8451$	*	$\bar{Y} = -23369.13 + 12203.47 X$
6	Root potassium (%)	$r = 0.2160$	-	$\bar{Y} = -7892.69 + 7115.13 X$
IV QUALITY				
Association of quality characters with yield				
1	Number of starch granules	$r = 0.9623$	**	$\bar{Y} = 20.979 + 0.000678 X$
2	Starch (%)	$r = 0.9391$	**	$\bar{Y} = 6.7026 + 0.0000354 X$
3	Crude fibre (%)	$r = 0.9297$	**	$\bar{Y} = 1.5979 + 0.000245 X$
4	Leaf bitter principles (%)	$r = -0.389$	-	$\bar{Y} = 4.9018 - 0.00000136 X$
5	Root bitter principles (%)	$r = 0.7403$	**	$\bar{Y} = 3.166 + 0.0000134 X$
6	Reducing sugar (%)	$r = 0.9598$	**	$\bar{Y} = 3.9954 + 0.0000153 X$
7	Non-reducing sugar (%)	$r = 0.9114$	**	$\bar{Y} = 7.2869 + 0.0000161 X$
8	Total sugar (%)	$r = 0.9377$	**	$\bar{Y} = 1.1242 + 0.00000114 X$
9	Fructose (%)	$r = 0.7928$	**	$\bar{Y} = 22.3129 + 0.000253 X$
10	Glucose (%)	$r = 0.7386$	**	$\bar{Y} = 5.7611 + 0.0000552 X$
11	Specific gravity of the infusion	$r = 0.9563$	**	$\bar{Y} = 1.004 + 0.00000652 X$
12	Leaf protein (%)	$r = 0.8124$	**	$\bar{Y} = 1.1141 + 0.00000285 X$
13	Root protein (%)	$r = 0.8798$	**	$\bar{Y} = 3.3999 + 0.000008165 X$
14	Leaf amino-acids (ug/g)	$r = 0.2632$	-	$\bar{Y} = 1924.81 + 0.000354 X$
15	Root amino-acids (ug/g)	$r = 0.4618$	-	$\bar{Y} = 3238.31 + 0.0150 X$
V ENZYME ACTIVITY				
1	IAA oxidase in leaf	$r = -0.9144$	**	$\bar{Y} = 288.04 - 0.000229 X$
2	IAA oxidase in root	$r = -0.8431$	**	$\bar{Y} = 247.27 - 0.000824 X$
3	Peroxisase in leaf	$r = 0.6149$	*	$\bar{Y} = 0.0052 + 0.0000000384 X$
4	Peroxisase in root	$r = 0.8359$	**	$\bar{Y} = 0.0056 + 0.000000554 X$
5	Catalase in leaf	$r = 0.4273$	-	$\bar{Y} = 4.886 + 0.000000286 X$
6	Catalase in root	$r = -0.8573$	**	$\bar{Y} = 6.0835 + 0.000000776 X$
VI ENDOGENOUS HORMONES				
1	Auxin in leaf	$r = -0.8285$	**	$\bar{Y} = 4.7075 + 0.00000343 X$
2	Auxin in root	$r = -0.8394$	**	$\bar{Y} = 4.9031 + 0.00000414 X$
3	Gibberellin in leaf	$r = 0.0797$	-	$\bar{Y} = 4.2079 + 0.000000476 X$
4	Gibberellin in root	$r = 0.1082$	-	$\bar{Y} = 4.7400 + 0.0000008405 X$
5	Cytokinin in leaf	$r = 0.3864$	-	$\bar{Y} = 4.898 + 0.000000192 X$
6	Cytokinin in root	$r = 0.3837$	-	$\bar{Y} = 4.8024 + 0.000000388 X$
7	ABA in leaf	$r = 0.8587$	*	$\bar{Y} = 32.7088 + 0.0000488 X$
8	ABA in root	$r = 0.2848$	-	$\bar{Y} = 36.245 + 0.0000356 X$

Table 46 EFFECT OF GA₃ AND VERNALISATION OF PERCENTAGE GERMINATION, NUMBER OF DAYS FOR FLOWERING, HEIGHT OF THE PLANTS, NUMBER OF BRANCHES AND MEAN SEED YIELD OF CHICORY

Treatment	Germination percent (over control)	Mean number of days for flowering	Mean height of plants on 120th day (cm)	Mean number of branches per plant on 120th day	Mean seed yield per plant (g)
T1	89.50	61.25	132.67	20.25	3.73
T2	85.75	56.75	120.75	21.14	3.95
T3	90.50	71.50	114.75	22.50	4.58
T4	88.75	69.00	119.69	23.75	4.85
T5	113.25	79.25	93.50	16.28	3.63
T6	117.25	71.75	98.46	15.69	3.60
T7	89.00	107.00	53.00	13.50	2.09
T8	100.00	115.50	49.28	13.65	1.99
S.E.	2.324	3.079	1.968	0.695	0.164
CD(P=0.05)	6.974	9.237	5.904	2.095	0.492

Details of treatments

T1	GA ₃	250 ppm + vernalisation for 30 days
T2	GA ₃	500 ppm + vernalisation for 30 days
T3	GA ₃	250 ppm + vernalisation for 10 days
T4	GA ₃	500 ppm + vernalisation for 10 days
T5	GA ₃	250 ppm + vernalisation for one day
T6	GA ₃	500 ppm + vernalisation for one day
T7	Seed soaked in water + vernalisation for one day	
T8	Control (no treatment)	



raised from water soaked and vernalised seeds and control plants recorded the least height (58.00 and 49.28 cm). The low concentration of GA in T1 and high concentration in T4 and T6 registered a greater height irrespective of the same vernalisation period.

4:3:1:4 Number of branches per plant

Number of branches was significantly higher in T4 (23.75) and T3 (22.50), followed by T2 and T1 (21.14 and 20.25). The water soaked treatment had less number of branches than no treatment. The high concentration of GA in T2 and T4 had induced more number of branches.

4:3:1:5 Seed yield per plant

The per plant seed yield was significantly high in T4 treatment (4.85 g), followed by T3 (4.58 g). The seed yield in T2 and T1 were 3.95 g and 3.73 g respectively. The plants raised from water soaked seeds and no treatment registered very low seed yields. The higher concentration of GA (500 ppm) in T4, T2 and T6 had induced greater seed yields irrespective of the duration of vernalisation treatment.

4:3:2 Performance of seeds obtained from GA₃ and vernalised treatments

A field experiment was conducted with the seeds obtained from GA and vernalised treatments. The germination

percentage, percentage of bolted plants, fresh weight of the roots, dry weight of the roots and percentage of dry matter production were recorded (Table 47)

4:3:2:1 Germination percentage

Significantly high germination percentage was obtained in T4 (110.32) and T3 (110.35) which were on par. All the other treatments recorded less germination than control.

4:3:2:2 Percentage of bolted plants

The percentage of bolted plants was high in the control T8 (26.3%) and T7 (16.8%). The percentage of bolted plants was low in T5 and T6 (5.8% and 5.9%) indicating that lesser duration of vernalisation led to low bolting percentage. Both the concentrations of GA and vernalisation for 30 days and 10 days recorded no bolting. The differences due to treatments were not however, significant.

4:3:2:3 Fresh weight of the chicory roots

The fresh weight of the chicory roots was significantly the highest in T4 treatment (25354 kg/ha), followed by T3 (21181 kg/ha). These two treatments were on par. Next to T3, T2 registered the fresh root weight of 23140 kg/ha. Though water soaked seeds vernalised for one day recorded a little higher yield than control, the increase in yield was not substantial. The high concentration

Table 47 PERFORMANCE OF SEEDS OBTAINED FROM GA₃ AND VERNALISATION TREATMENTS ON GERMINATION, BOLTED PLANTS, FRESH AND DRY WEIGHT OF CHICORY ROOTS

Treatment	Germination percent over control	Percentage of bolted plants	Fresh weight of roots (kg/ha)	Dry weight of chicory roots (kg/ha)	Percentage of dry matter production
T1	98.35	-	23120	7358	31.82
T2	95.82	-	23140	7335	22.56
T3	110.35	-	25181	8646	34.33
T4	114.32	-	25354	8658	34.15
T5	92.39	5.8	19356	5937	30.68
T6	90.69	5.9	19617	5968	30.43
T7	90.37	16.8	17949	5308	29.56
T8	100.00	26.3	16153	4640	28.73
S.E.	1.607	NS	211.4	31.56	-
CD (P=0.05)	4.821		634.2	94.68	-

Details of treatments :

- T1 GA₃ 250 ppm + vernalisation for 30 days
- T2 GA₃ 500 ppm + vernalisation for 30 days
- T3 GA₃ 250 ppm + vernalisation for 10 days
- T4 GA₃ 500 ppm + vernalisation for 10 days
- T5 GA₃ 250 ppm + vernalisation for 1 day
- T6 GA₃ 500 ppm + vernalisation for 1 day
- T7 Seed soaked in water + vernalisation for 1 day
- T8 Control (no treatment)

of GA in the treatments T2, T4 and T6 had registered higher yield than low concentrations irrespective of the duration of vernalisation.

4:3:2:4 Dry matter production

A high percentage of dry matter production was recorded in T4 (34.15%) and T3 (34.33). T2 and T1 registered 32.56% and 31.82% of dry matter respectively, which was followed by T5 and T6 treatments (30.68% and 30.43%). All the treatments registered higher percentage of dry matter production than the control plants.

DISCUSSION

5. DISCUSSION

5.1 Months of sowing

Major differences in the growth cycle of root crops emerge on the basis of overall length of the growth period and relative timing, duration and magnitude of shoot and tuber growth. The productivity of a root crop depends on its response to environmental conditions which affect all or most of the characteristics of growth pattern. One of the major environmental factors which affect such growth pattern is an early onset of unfavourable season. Chicory grows well under conditions of medium temperature, high light intensity and ample rainfall, provided there is good drainage during the growing period but moderately dry weather is favourable to formation and development of the tuberous roots. In order to regulate the tuberization processes to the best advantage, the optimum time of sowing the crop is of prime importance.

5.1.1 Growth

It is well known that environmental cues are utilised by plants to synchronize early shoot growth and tuber initiation. The present study with chicory has revealed that the production of leaves from the 30th day after sowing till the 90th day was markedly high contributing to vigorous early shoot growth. A differential response was found in the leaf number among the different months of sowing indicating seasonal influence on growth. Though the leaf area also followed the same trend

as leaf number, it was relatively high in crops sown during August, December, October and November (Table 5). The highest fresh weights of roots were also recorded in the months of October, November and December (Table 8). Leaf number and leaf area are the photosynthetic units for dry matter production; they were perceptibly influenced by the months of sowing. July and August recorded higher values for both these parameters. Possibly excessive vegetative growth was inimical to root growth. The high fresh root yield from October to December should be considered as a natural sequence of flow of photosynthates from leaf to the roots as a result of moderately vigorous vegetative growth. According to Spaldon and Kransko (1963) delayed sowing lowers root weight. It is to be presumed that late sowing reduces the leaf area. In the present study, there was continuous addition of leaves to the canopy during tuberization. The length of time before full canopy was achieved after sowing acted as a major limitation for optimal root growth. Though, August sowing had a high leaf number and leaf area, this was not reflected on the tuber yield. In sweet potato, high root bulking did not occur during the rapid shoot growth stage (Chatterjee and Mandal, 1976). Sishachakr *et al.* (1982) noted that in sweet potato, the tuberizing ability was negatively correlated to later leaf growth and beyond initial phase tuberization became independent of lamina size. It is possible that the situation was similar in chicory.

Environmental conditions which optimise these opposing effects are desirable during the early stages of development of root crops. The mean length, girth and weight of the root were high in October, September and November sowings which indicated that environmental conditions subsequent to sowing were favourable for optimal tuber initiation and development. The crops sown in April and May recorded low values for mean weight, length and girth of the roots. These crops had a higher shoot growth in the early period which possibly, caused an inhibitory effect on tuber initiation and further development. It was interesting that October sown crop showed a high root girth/length ratio. In other words, the bulking which incidentally increased the girth due to carbohydrate storage and early deposition of dry matter was favourably influenced by the seasonal conditions that obtained during the crop growth. Such an antagonism between early vegetative growth which caused only fibrous root development and later development of storage organ has been observed by Loomis and Williams (1969) in sweet potato. The crop sown during October had high productive attributes such as length, girth and weight of the root. It is clear that temperature and intensity of light influenced productivity (Table 12). RTD and PTU have shown a negative association with yield.

Bolting is a characteristic response of most tuber crops often due to unfavourable environmental factors. In the present study, bolting was high in March, April and May sowings even on the 80th day after sowing. On the 110th and 120th day, bolting was noted in all the months of sowing from January to August and December. No bolting was recorded in September, October and November sowings. These provide additional evidence that elongation of main axis into reproductive parts was partly mediated by environmental influences. This is again brought out clearly by the high positive relationship of PTU with the percentage of bolting. High temperature accompanied by longer duration of more intense sun light were favourable for flowering. Sowing during September, October and November showed no bolting and during these periods PTU was less. Sundararaj and Thulasidas (1976) also observed that April and May sown crops flowered earlier and tuber formation was adversely affected.

5.1.2 Yield

The root fresh weight as well as top fresh weight were high in October, November and December sown crops. The root fresh weight had a negative relationship with RTD and PTU (Table 12). In sweet potato Uexkull (1965) recorded a positive relationship between RTD and yield. But sweet potato being a short day plant, the positive influence of RTD is understandable whereas chicory has been said to behave as a long day plant

with thermo-inductive nature (Wareing and Phillips, 1978) . Its response to temperature and photoperiod would therefore differ from that of sweet potato. The present study indicated that the chicory crop required a mild climate with moderate temperature range. This is amply evidenced from the effect of sowing time on yield of chicory which was appreciable. According to Spalden and Krususko (1963) mid-April sowing recorded high yield and subsequent delay in sowing in Russia resulted in loss of yield. Van Hossin and Andersen (1963) noted that April sowing resulted in high yield. Mid-May sowing for high yield was recommended by Kaufmann (1965). But these were relevant to conditions in countries enjoying temperate climates. Therefore, the results of the present study do not, nor can they be expected to follow the same trend. But, the results with chicory in other countries at least serve to emphasis the important roles played by the sowing time, more particularly that of the temperature regime during the growth and tuberisation stages.

The crop sown in October gave high dry matter production of tops, roots and harvest index. These attributes in the crops sown in September, November and December were also higher than in the other months. The values for RTD and PTU for these months were less and had a negative relationship with root yield. One of the important features was the relationship of temperature disparity (which, in effect means

diurnal variation, i.e., difference between day and night temperature) on the yield between the crop sown in April (low yield) and October (high yield). In the former case, the temperature disparity decreased from 15.7°C at the time of sowing (Table 1) to 7.1°C at the time of harvest. The disparity ranged between 6.1°C to 8.6°C in October and November but from the latter half of December rose steadily from 10.4°C to 15.3°C (at harvest). The data in Table 1 also reveal that the day (maximum) temperature had shown greater variations than night (minimum temperature). In other words relatively lower day temperature and lower temperature disparity in the growth stage (approximately about 70-80 days from sowing) appear to favour tuber development as exemplified by October-sown crop. This is apparently mediated through greater translocation of photosynthates to the sink (root) because both day as well as night temperatures were relatively lower in the early growth stage in crops sown in September to December. The low diurnal temperature disparity has also helped to prevent loss of photosynthates by reducing photo-respiration. A parallel observation was made in sweet potato by Loomis and Williams (1969). The harvest index was high in October sown crop and was low in the April sown crop. Harvest index is a measure of the distribution of dry matter between the roots (tubers) and the other organs of the plant. It is known that the major source of yield variation is the competition pressure that develops in the

course of the growth cycle. As discussed earlier, October sown crop had better shoot growth and the initial crop growth rate was also relatively higher which led to early tuber initiation and high yield.

In the present study, it was found that the net assimilation rate (NAR) progressively increased from 30th day and attained the highest value at final harvest but the values were of a greater magnitude from 60th to 90th day. NAR values are highly sensitive to environment since they integrate the daily pattern of temperature and solar radiation as well as the manner and density of leaf display and the respiratory activities of non-foliage parts. Among the months of sowing, October sown crop had shown high NAR at all the stages indicating that the interacting environmental influences were favourable for high yield. NAR was related to PTU and had high negative relationship indicating high PTU was unfavourable for NAR. The relative growth rate (RGR) was also found to increase from 30th to 120th day irrespective of months of sowing. October sowing recorded the highest RGR in all phases but was the least in April sown crop which experienced high PTU. No clear cut relationship could however be established between RGR and PTU.

5.1.3 Nutrients

The differences in the N, P, K contents in leaf and root among different months of sowing at various stages of growth were in general, not significant except for stray

instances. These do not deserve any special mention. The brief discussion that follows relates more to the trend of values. In the initial phases, leaf nitrogen content was high as observed in sweet potato (Leonard et al. 1949) and high leaf nitrogen and low root nitrogen in the initial phases were noted by Delegher et al. (1980) in chicory.

The leaf phosphorus content progressively declined from the 30th day to 120th day. The root phosphorus content did not follow any clear pattern.

The leaf potassium content was found to increase with the age of the plant and was high in the October sown crop. The potassium content was higher than that of nitrogen and phosphorus both in leaves and roots. The root potassium content was higher than leaf potassium. The chicory plant thus appears to absorb more potassium. In sweet potato, dry matter production was associated with increase in potassium content (Sharma et al. 1978). It has been shown that increased potassium, prolonged the leaf area duration. When potassium was increased, excessive top growth was greatly suppressed even under high nitrogen conditions and higher tuberous root yield was accordingly produced. Increase in the level of potassium might accelerate the translocation of photosynthates and was effective in increasing the size of sink or tuberous root as noted in sweet potato (Tsumo and Fujisai, 1963).

5.1.4 Quality

The reducing sugar, non-reducing sugar and total sugars were high in the October sown crop and April and May sown crops registered the least value. Increase in sugar may be accounted for by the effect of low temperature (Arreguin-Lozano and Bonner, 1949). Low night temperature was found to enhance sugar content and water soluble carbohydrate (Ulrich, 1952) and to decrease sucrose percentage in sugarbeet (Doney et al. 1981). In the present study the glucose concentration in the reducing sugar was the lowest in November and October sown crops and the highest in July sowing. The fructose concentrations in the reducing sugar was high in November and October sown crops. This may be attributed to the low night temperatures which prevailed during the months from October to January which constituted the tuber initiation and development stages. In sugar beet, low night temperature favoured the sugar content (Ivins and Bremner, 1966). Lowered night temperature was shown to effect improvements in the growth, bulking and sugar content in sweet potato (Wilson, 1967).

High crude fibre content was noted in April and May sowings and the value was low in October sowing. Consistent differences in the crude fibre content in different seasons were earlier noted in chicory (Orchard and Van Rooyen, 1953). PTU was positively associated with crude fibre content indicating high PTU was favourable for greater crude fibre

content in chicory. This explains why crop sown in April and May developed tubers with higher crude fibre content.

The content of bitter principles (which is an important quality constituent) was high in October sown crop and was low in July and June sown crops. A higher content of bitter principles in the tuber is desirable for imparting the characteristic cup quality of chicory blended coffee. The specific gravity of infusion obtained from tubers of October sown crop showed the highest value. The starch content was high in July sown crop and it had a positive relationship with PTU. This is in line with the findings of Wassink (1953) in artichoke. It is interesting that the contents of starch and bitter principles have shown opposite trends. In other words, it is clear that a low starch content and high bitter principles content would be desirable and these are clearly influenced by PTU.

A moderate leaf and root protein was noted in November, December and October sown crop. Leaf and root protein content do not seem to be related to time of sowing as observed by Doney et al. (1981). Protein formed an alternate sink if nitrogen supply was great (Wilson, 1969).

5.1.5 Enzyme activity

A low IAA oxidase activity during October, November and December sowings was noted whereas auxin activity was high during these months. May, March & April registered

high IAA oxidase activity and auxin activity was low during these months. The IAA oxidase activity tended to be comparatively low during the period of relatively high auxin content. This would show that high auxin content is favourable for prevention of bolting and thus indirectly promoting greater tuberization. Such inverse relationships between IAA oxidase activity and auxin content was observed in peas by Moore (1980). Peroxidase activity was high in April sown crop and was low in crop sown in October. The catalase activity was high in October sown crop and was low in May and June sown crops. Galston and Dalberg (1954) showed that IAA oxidase activity was high in the roots than meristem cells of chicory and peroxidase activity increased with increase in the age of the tissue. The activities of peroxidase and catalase also differed in different months of sowing. An indication has thus been obtained that high peroxidase activity and low catalase activity interact physiologically to cause bolting and thereby to reduce tuber yields in certain months as discussed. IAA oxidase activity in leaves and roots and peroxidase and catalase activity in the roots exhibited a positive relationship with PTU.

5.1.6 Endogenous hormonal changes

Very little work has been reported on the possible role of auxin on the actual processes of tuberization. Davis (1941) opined that auxin may accelerate the formation of tubers and promote their growth, though it had no specific

tuber inducing effect. Tuberous growth with auxin and coconut milk reported by Morrel and Wetmore (1951) and Chopman (1958) provide an indication of auxin in the role of tuberization. The findings of Melansan and Trewavas (1982) about the involvement of auxin in the synthesis of protein and control of gene expression eventually leading to DNA synthesis, led to the idea of triggering mechanism of auxin. Auxin content in the leaves and roots in the present study had positive relationship with PTU of the respective months of sowing. The fact that the auxin activity was high in the early phases indicated its involvement in the early shoot growth which in turn led to early root growth and high yield in the crops sown from September to November. The action of auxin thus on tuberization was indirect.

The low gibberellin activity and content in October and November coincided with high yield. This result has confirmed that gibberellin does not favour tuberization (Railton and Wareing, 1953). In crops sown in April and May a high percentage of bolting was noted. These months had also a higher content of gibberellin which might be in supra optimal concentration, inducing the capitulum to elongate and to form flowers prematurely. This also indicated that gibberellin inhibited tuberization but promoted bolting.

High cytokinin activity was noted in the crop sown from September to December in all phases of growth. In chicory, Vardjan and Nitsch (1961) reported high kinin

activity in the apical part. A high activity in the root stem transition region and hormonal control of vascular cambium by kinin have been reported by Torrey (1965). Cytokinin induced secondary thickening in radish (Radin and Loomis, 1971). High cytokinin at the apical end has also been reported (Wareing and Phillips, 1978). In the present study, high cytokinin activity in the crop sown in October which produced high yield suggested that cytokinin is actively involved in enhancing the tuber growth possibly by its mobilising influence on directional transport of metabolites to the root. The cytokinin content in the leaves and roots had a negative relationship with PTU. This would explain the seasonal influence on tuberization.

Inhibitors do not appear to play any significant role in tuberization in chicory. Similar observation was recorded in Dahlia (Halevy and Brian, 1975).

The assessment of involvement of plant growth regulators of tuberization in photoperiodic susceptible species or species where temperatures determine the rate of tuberization may be complex. Auxin enhanced early shoot growth which indirectly aided in the early root growth and yield. Lawrence (1980) has shown that auxin induced cell elongation is dependent on new RNA and protein synthesis. In a later section, the relationship of proteins and amino acids in this crop has been discussed. Gibberellin induced bolting and inhibited tuberization. Cytokinin seems to be more closely involved in the processes of tuberization such as starch accumulation, secondary thickening, etc. The role

of inhibitions has not been brought out in the present study. The effect of growth substances particularly auxin and cytokinin seems to be mediated via the temperature and light (solar radiation). This is evidenced from the high negative correlation between PTU on the one hand and fresh and dry weight of tops and roots NAR and cytokinin on the other. High positive association was exhibited between PTU on the one hand and auxin, gibberellin and several enzymes as well as bolting on the other.

5:2 Stages of harvest

As the storage root reaches the end of the growth, it may undergo some characteristic qualitative changes, which are collectively referred to as tuber maturation. To clarify the terms, the word maturation refers to the processes associated with root reaching full size and ripening refers to the processes which qualitatively transform the mature storage roots. The events leading to the maturity in the storage roots are subtle. The tuber maturation is associated with a marked drop in sugar content. Associated with the sugar decline is an increase in the starch content. The harvest should coincide with maximum maturity with all desirable quality attributes. In crops like chicory where the active principle is localised in the storage roots it is difficult to assess the stage of maturity externally.

5:2:1 Growth

The production of leaves was high from the 105th to 120th day and beyond that stage it seemed to be static. The leaf area was the highest at 135 days after sowing and a little reduction was noted subsequent to this stage. A progressive increase in the number of leaves and leaf area upto 120th and 135th day respectively was noted and this was maintained till final harvest. These patterns of the growth in chicory are in tune with other root crops such as sweet potato and sugar beet. In sweet potato and beet the plants continue to add new leaves to the canopy during tuberisation and are able to maintain a reasonable leaf area throughout the season (Loomis and Bennett, 1966). Leaf area was chosen as a parameter for expressing differences in the growth patterns of root crops because leaf area was a measure of the effective leaf surface exposed to sunlight for photosynthesis (Wilson, 1977).

The length of the root in chicory showed a sharp increase between 90 to 105 days after sowing, though there was a progressive increase from 30th day to 120th day. The girth of the root also showed a similar pattern but attained the highest value at 150th day after sowing. The length/girth ratio in the early stages was low and had greater value only after the 105th day after sowing. The highest mean weight of root was obtained at the 150th day. Ivins and Bremner (1966)

observed a similar pattern in sugarbeet. Tuber development depended largely on the increase in the tuber girth. In the present study impressive increase in girth and weight of the root concomitantly was noted upto the 120th day. Togari (1950) has expressed the view that roots of larger diameter are likely to differentiate into larger tubers. Such an inter-relationship between girth and weight of roots suggests that root girth is the most important single dimensional trait indicative of high yield as evidenced from this study. Chicory, being a root crop, where storage organ growth began early in the phase and continued throughout the vegetative phase of the plant, there was an indeterminate competition between shoot growth and storage organ growth. Here shoot growth retained priority for assimilate supply even though, the relative magnitude of top and root may change as root size increases. Loomis and Rappaport (1976) have made similar observations in sugarbeet.

The increase in the root girth/length ratio with advancement of age was noted in chicory. The tuber length, girth and girth/length ratio formed an indication for the pattern of development. In chicory, the root girth/length ratio was low in the early stages, attained maximum on 120th day and declined thereafter indicating the initiation of root development in the early phase and full development on the

120th day after sowing. The development beyond 120th day was only a marginal. Similar pattern was noted in sugar beet (Loomis and Rappaport, 1976).

5.2.2 Yield

The highest fresh weight of tops and roots was obtained on the 120th day after sowing. A balance between the fresh weight of tops and roots was maintained throughout the growing season. The balancing mechanism between shoot and storage organ growth may be based on several functional activities (Loomis and Rappaport, 1976). A continual increase in the shoot organ growth and storage organ growth in chicory (Chaurasia *et al.* 1971), in medicinal yam (Vasanthakumar and Chacko, 1980) are a few previous results. It is worthy to mention that in the present study the fresh weight of root was the highest on the 120th day harvest but delaying harvest beyond this stage did not materially affect the root yield except for reduction ranging from 156 to 960 grams per ha. But different stages of harvest for fresh root weight have been recommended. Orchard and Van Rooyen (1953) observed that there would not be any increase in the weight of chicory root once maturity was reached. An increased root yield with later harvest in chicory was suggested by Thulesidas and Chandra Mohan (1964) and in Jerusalem artichoke by Dorrell and Chabey (1977). These differential influence of the dates of harvest on fresh yield may be due to different agro-climatic

conditions wherein the influence of the eco-physiology on crop play an important role as discussed earlier. Between 90 and 165 days after sowing, the top/root ratios showed narrow values ranging from 1.10 to 1.13. The variation in the ratios was more due to root weight. Based on this parameter, harvesting when the crop is 120 days old from sowing seems advisable.

The dry matter production in root and tops was also high on the 120th day after sowing. Delayed harvest after 135th day resulted in decrease in dry weight of roots. Similar findings were noted in Jerusalem artichoke (Dorrell and Chubey, 1977), in sweet potato (Sampathkumar, 1979) in sugarbeet (Bagchi and Chanda, 1980) and in coleus (Vijayakumar, 1982). A contrasting finding was reported by Chaurasia *et al.* (1971). According to them the dry matter of chicory continued to increase with an increase in the harvesting period and was less when harvested after 120 days under Punjab conditions where the longer duration might be due to difference in climatic conditions. The dry matter of root had a positive relationship with yield. Since the tuberous root comprises a high proportion of total dry weight, the increase in total dry matter has a direct connection with tuberous root yield. Productivity of the tuberous root is, therefore, primarily a function of dry matter production. The total production of dry matter as well as the distribution to the roots of the portion of dry matter surplus to that necessary for

maintenance of the individual plant are the ultimate determinants of yield. In chicory, though there was continual shoot growth throughout the growing period, a high dry matter production was obtained on the 120th day itself.

The harvest index ranged narrowly from the 120th day to 180th day of harvest. Dry matter distribution to root is otherwise called harvest index (Wilson, 1977). The harvest index had a high positive relationship with yield. The distribution of dry matter between roots and other organs of the plants was low in the early stages, reached a high value on the 120th day and thereafter the increase was only minimal, which indicated that correspondingly high dry matter distribution both in the tops and roots took place.

The net assimilation rate and relative growth rate were progressively increasing upto 120th day and declined thereafter. The early growth rate is a major determinant of the lengths of crop growth period. NAR provided information about the physiological properties of the particular photosynthetic system. High NAR and RGR on 120th day of chicory crop indicated the optimal stage of harvest.

The present study lends support to the postulation that high leaf number and leaf area, increase in the root length, girth and its ratio, increase in root weight, high fresh top weight and harvest index were associated with the

tuber yield. The growth components such as leaf number, leaf area, root length, root girth, fresh weight of tops, dry weight of roots and tops, NAR, RGR, and harvest index showed a close positive relationship with yield. Such relationship was also observed in cassava (Lowe and Wilson, 1974) and in coleus (Vijayakumar, 1982). Significant positive correlation between yield components (Table 45) suggested the contribution of the various growth characters to the total root yield in this crop. These characters are in turn influenced by the time of sowing and the temperature and light regimes prevailing during the growth period. These are the possible involvement of endogenous levels of plant growth substances have already been discussed in the previous section.

5.2.3 Nutrition

Nitrogen content in the leaves and roots was of a higher order during the early stages of harvest and declined in the later stages. Selvaraj (1981) observed a similar trend in chicory. It was obvious that a large amount of nitrogen was utilised both by foliage and roots (Duncan et al. 1968) and in radish accumulation of nitrogen was more in shoots than in roots (Muthuswami, 1968). Nitrogen increases dry matter production by increasing the expansion of leaf area and the distribution of dry matter to the above ground parts. There was increase in leaf and nitrogen upto 60th day which declined thereafter. Similar observations

were made in sweet potato (Tsuno and Fujise, 1965). Distribution of dry matter was affected by nitrogen content in the leaf blade. When nitrogen content was high most of the photosynthates were utilised for top growth. In the present study there was increase in nitrogen level upto the 60th day. At that stage dry matter production was less whereas top/root ratio was relatively high. The leaf and root N showed a negative relationship with yield.

The phosphorus content in the leaves and roots did not show any significant differences. The absorption of phosphorus in general was small (Duncan, et al. 1958) and its accumulation was more in the roots than in the leaves (Muthuswami, 1968). A close relationship of leaf P with carrot yield was noted by Pankov (1976). But the present study has indicated a negative relationship between yield and phosphorus content of leaf and root.

The leaf potassium content was high on 120th day and a slight decrease in its content was noted in the last stage. But the decrease from 120th day to 180th day was not steep and the values differed narrowly. It is well known that among mineral nutrients, potassium affects tuberous root yield by increasing net photosynthetic activity of a given leaf area. In sweet potato also, potassium was found essential for the enlargement and development of tubers and to increase the yield (Duncan et al. 1958). It is worthy

to mention that the potassium content in both leaves and tubers declined with the age of the plant after tuber maturity, which was in conformity with the findings of Scott and Bouwkamp, 1975). Leaf potassium had a positive relationship with yield but no such correlation with root potassium could be established.

5:2:4 Quality

In the initial stage, the starch granules accumulation in the top, middle and bottom portion of chicory root was low and increased progressively in the later stages of growth and attained the highest value on the 135th day. When harvest was delayed beyond the 135th day, the starch granule accumulation also decreased. Starch granule accumulation had a positive relationship with yield. For tuber bulking accumulation of starch granules was necessary. Early starch deposition in the first produced parenchyma cells has been observed to occur 25 days after planting in cassava and there was a progressively increasing deposition as the plant aged (Hunt et al. 1977).

The increase in starch content between 45 and 60 days and from 75 to 120 day was remarkable. This shows that in chicory root development there were two distinct and crucial phases when greater starch mobilisation takes place. These two stages, in practical terms may be considered to occur

45 days after sowing and 75 days after sowing respectively. This is of great significance in the management of cultural operations to get high yield and quality. Actually, the tuber yield is otherwise called dry matter production which is due to 'tuber bulking'. The tuber bulking of the tuberous root occurred shortly after the production of xylem parenchyma cells and a little later, deposition of starch begins. Earlier it was found that there was gradual increase in the starch content during the growing season and increased upto the final stage in chicory (Andersen, 1937). Starch storage in leaves increased when tuber formation was inhibited (Tsuno and Fujise, 1965). The starch content was high in sweet potato tubers as they advanced in age and increased in thickness (Edmond, 1971) and reached a peak on the 100th day (Sampathkumar, 1979). It is of interest that the greater starch accumulation in chicory coincided with the phase of growth where the temperature disparity of a particular magnitude has been shown to influence the tuber formation as discussed in a previous section.

The crude fibre content was low in the early stages and increased markedly from 105 and 120 days after sowing. The crude fibre content had a positive correlation with tuber yield. The presence of crude fibre was considered as an added quality attribute which imparted greater crop quality. Orchard and Van Rooyen (1953) stated that the percentage of

crude fibre formed a reliable index for reflecting the quality of the dried roots. A high percentage of crude fibre content was noted when the roots were harvested after 120th day of sowing in the present investigation.

In the leaves and roots the bitter principles content was high on 120th and 135th day respectively and there was a reduction in the subsequent stages. When compared to leaves, roots were found to contain a greater quantity after 75 days. The bitter principles in chicory constituted of lactucopicrin (Orchard and Van Rooyen, 1953) and glucoside of the fructose (Carsvaggi and Manfredi, 1937). The bitter principles had a positive correlation with yield.

In the early stages of harvest, reducing sugar was low and increased progressively and reached a peak at the 150th day. High non-reducing sugar between 120 and 135 days was noted. The total sugar also followed the same trend. Though there was a slight difference between the 120th to 135th in respect of total, reducing and non-reducing sugars, their values were on par. Hence harvesting could be done on 120th day without reducing the sugar level. Determination of reducing sugar would give good comparative values of sugar present in different stages of root (Orchard and Van Rooyen, 1953). Rutherford and Flood (1971) noted low sugar content in sugar content in sugar beet in delayed harvest. Similarly, a high soluble sugar in the early stages and a declining trend later has been observed in sweet potato (Edmond, 1971).

The reducing sugar on fresh weight basis was low in the initial stage between 90 and 105 days and attained the highest value on the 120th day. The percentage of fructose in the reducing sugar was high on 120th day and declined in subsequent harvest. The glucose percentage showed an inconsistent trend. Fructose and glucose concentration of the reducing sugars showed a positive relationship with root yield. The fructose level dropped during final harvest (Rutherford and Flood, 1971); bound fructose increased and bound glucose decreased with the advancement in the growth of the roots (Bhatia *et al.* 1974). A decline in fructose concentration with delay in harvest (Plinik and Vervelde, 1976) and increased total sugars and glucose concentration and decreased fructose concentration when the crop was harvested after 125 days (Chubey and Dorrell 1974) have been earlier reported and these lend support to the present findings. The stage of harvest has a pronounced effect on the quality of roots. The protein content formed a reliable index reflecting the quality of the root (Orchard and Van Rooyen, 1953). An upward trend upto 105 days in protein content was noted in sweet potato (Sampathkumar, 1979) whereas in coleus the protein percentage was high upto 120th day and there was no variation in the subsequent harvests. In the present study with chicory also, a progressive increase in leaf and root protein contents upto a particular stage and a decline thereafter, have been observed. Root protein content showed the highest value when the roots were harvested in the 120th day.

The specific gravity of the chicory infusion is a sure index of quality. The specific gravity of coffee beans was 1.008 and in the chicory roots harvested on 120th day, the value was at the highest magnitude indicating the harvesting of roots on 120th day was optimum.

5:2:5 Other attributes

The total aminoacids content was higher on the 120th day both in leaves and roots. At the 120th day the histidine content was high. This aminoacids provided flavour on roasting (Diemair, 1940). Glutamic acid was present in the roots on the 75th day and 120 days but was absent in the roots on the 180th day although it was present in the leaves at that stage. Glutamic acid occupies an unique position as a mediator between nitrogen and carbon metabolism and most of the amino acids are channelled through the glutamic acid (Loomis and Stumpf, 1958). Among the amino acids, free proline and free arginine were found to increase as the plant ages. They are involved in the synthesis of protein (Bonuniols, 1974).

The enzyme IAA oxidase was high in the early stages. The root yield showed a negative relationship with leaf and root IAA oxidase activity, since IAA oxidase activity tended to be high during the period of low auxin synthesis (Moore, 1980), this suggests that high auxin was antagonistic to tuber development. The enzyme peroxidase was found to

increase from the initial stage to final stage and had positive relationship with yield. The catalase activity was high on the 90th day and had a negative relative relationship with yield. The crop growth and productivity was strongly influenced by the enzyme peroxidase which showed progressively increasing trend with increase in the age of the plant at harvest.

5:2:6 Hormonal changes

High auxin content was detected in the early stages and it declined from 45th day onward indicating that auxin level decreased when tuberization began thus establishing the antagonism between auxin and tuberization. The gibberellin content in leaves and roots was fairly high beyond the 120th day. The cytokinin content in the leaves and roots increased progressively and was high on the 120th day. The inhibitor content in the leaves and roots during early stages was low and increased progressively and was high in the final stages. Thus we find here a paradoxical situation. High root yield was secured when the crop was harvested 120 days after sowing. Prior to that stage auxin and gibberellin contents in leaves and roots were high, cytokinins were also similarly high but the inhibitor level was fairly low. The above results indicate that hormones do not serve as quantitative control agents over the degree of tuberization; instead, they may act as switches to initiate events (Lawrence and Barker, 1963).

Gibberellin was found to inhibit tuberization (Railton and Wareing, 1953) whereas inhibitor content promoted tuberization in Dahlias (Brian et al. 1974). The differing levels of endogenous growth substances such as auxins, gibberellins, and cytokinins in the early stages (prior to 120th day) suggest that they had interacted to direct the flow of metabolites to the sink (roots). Of these the role of cytokinin seems to be more predominant as discussed in the previous section.

5.3 Effect of gibberellin and vernalization on the chicory seed yield

The performance of the chicory seeds obtained from the bolters are not comparable with that of the seeds from over-wintered plants. Hence for a sound seed production programme, proper technology has to be developed. Cold treatments (vernalisation) and/or treatment with GA offer potentials in this regard.

The pretreated seeds with GA (550 ppm) and vernalised for one day registered high percentage of germination. A low germination percentage in general was recorded in treatments involving longer duration of vernalization. Low temperature response was apparently due to production of growth stimulation (Wareing and Villiers, 1961). GA was active in breaking seed dormancy induced by high temperature or

coumarin. The effect of GA applied together with low temperature was additive (Koller *et al.* 1962). The combined effect of gibberellin and vernalization led to earlier and uniform germination in chicory. The low germination in seeds subjected to longer exposure to cold is a matter to be investigated.

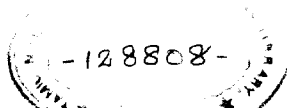
In the present study, earliest flowering occurred in plants raised from seeds treated with GA at 500 and 250 ppm and vernalised for 30 days. Among the concentration of GA, high concentration and among duration of vernalization, longer duration had greater influence than lower concentration of GA and shorter duration of cold exposure. Shooting and flowering by seed vernalization in turnip (Hartman, 1956), in rutabagas (Highkin, 1956) in seed lettuce (Rappaport and Wittwer, 1956), in sugarbeet (Chouard, 1960), in chicory (Rappaport and Wittwer, 1965) and in carrot (Gregory, 1965) have been reported earlier. GA was an effective substitute for chilling, sometimes, causing an extreme elongation and occasionally flowering. Flowering in endive was accelerated in gibberellin treated and vernalised seeds (Harrington and Rappaport, 1951). The consistent effects of GA on flowering (Harrington and Rappaport, 1957) and its effect of initiation of flowering in cold requiring species (Chailakhyan, 1958); promoting flowering in seed lettuce (Buckovac and Wittwer, 1958);

enhancement of flower primordia (Stoddart, 1959) and early flowering in cabbage, carrot, beet, turnip, chicory, endive, parsley, etc., (Lang and Reinhard, 1961) have been recorded.

When both gibberellin and vernalisation were combined, the effects were additive. The present study also revealed that seeds of chicory treated with gibberellin and vernalisation produced early shooting and flowering. A marked elongation of rosette shoot, greater percentage of flowering and high stem height are some of the remarkable effects due to GA.

Plants raised from chicory seeds treated with gibberellic acid and vernalised, produced high seed yield. Higher concentration of GA induced greater seed yield irrespective of the duration of vernalization treatment. High seed yield due to the combined effect of GA and vernalisation was observed by Harrington and Rappaport (1957).

High percentage of germination was recorded in seeds obtained from plants which were earlier subjected to GA at 500 (ppm) and 250 (ppm) and one day vernalization treatment. Both concentrations of GA and vernalization for 30 days and 10 days recorded no bolting. The fresh weight of the chicory roots and dry matter production were higher in the plants from seeds treated with higher concentrations of GA than lower concentrations irrespective of the duration



of vernalization. These results however, do not accord with earlier reports. Gibberellin treatment of chicory had no effect on germination of the resulting seed or growth of the subsequent crop (Wittwer, 1956; Harrington and Rappaport, 1957). The plants from vernalized seeds developed the same morphological characteristics of the overwintered plants (Rappaport and Wittwer, 1956). These workers compared the seeds from overwintered plants. But in the present study comparison was made with the seeds subjected to GA treatment and vernalization and untreated seeds. This would explain the differences noted in the present investigations.

Thus on practical consideration it could be seen that October sowing recorded high leaf number, leaf area, length and girth of the roots and its ratio, dry matter production, harvest index, NAR and RGR. The total sugars, reducing sugar, non-reducing sugar were also high in the crop sown in October. The starch content and crude fibre content had a low value. The leaf and root IAA oxidase activity and peroxidase were also low in October sowing. Cytokinin was found to be involved in the tuberization such as starch accumulation and secondary thickening. Among the stages of harvest, harvesting on the 120th day after sowing recorded high fresh root yield and dry matter production in addition to high quality roots. Gibberellin treated and vernalized seeds flowered earlier and produced high seed yield.

The seeds obtained from gibberellin-vernalisation treatment recorded good germination and no bolting with high root weight and dry matter production.

Thus the present study has helped to produce new technology for obtaining not only high root yield with good quality but also to produce seeds whose subsequent performance has been satisfactory. This could pave the way for greater interest in indigenous seed production and to obtain a high tonnage of chicory roots of optimal quality without dependence on other states or countries. The involvement of photothermal units and endogenous hormonal levels on growth and tuberization of chicory adds new information to the understanding of the physiology of chicory, grown in tropical areas.

JMMARY

SUMMARY

6. SUMMARY

Investigations were undertaken to find out the effect of different components of the environment on growth and development of chicory plant (Cichorium intybus L.). The effect of time of sowing, assessment of the optimum stage of harvest of the root and attempts to produce seeds through GA and vernalisation treatments were studied in separate experiments.

I Time of sowing trial

1. August sowing recorded the highest leaf number and leaf area. A progressive increase in the production of leaves from the 30th day to 90th day and declining trend later were noted. Higher production of leaves and higher leaf area were also noted in October, November and December sown crops.

2. Bolting was observed in March, April and May sowing as early as the 80th day after sowing but there was no bolting in September, October and November sowings.

3. October sowing recorded the highest mean weight of root. The length of the root was high in September as well as October sowing, but was less in March, April and May sown crops. The girth/length ratio was also high in October sown crop.

4. The crop sown in October registered high fresh weight of tops, fresh weight of roots and April and May sown crops recorded the least values. The top/root ratio was high in August crop and October sown crop had very low ratio.

5. The dry matter production of tops and roots was high in October sowing. April and May sown crops recorded the least value. The harvest index was high in October sowing and the least value was recorded in January and August sowing.

6. October sowing recorded high net assimilation rate (NAR) in all phases whereas March, April and May sowings recorded the least values. Irrespective of the month of sowing net assimilation rate showed a progressive increase from 30th day to 120th day.

7. The relative growth rate (RGR) was high in October sowing in all the phases. March, April and May sown crops recorded the least values.

8. A negative relationship between tuber yield and relative temperature disparity (RTD) was noted.

9. The photothermal units (PTU) registered a negative relationship with fresh root yield.

10. Leaf nitrogen content was high in October sown crop on the 30th, 60th and 120th days. October, November and December sown crops recorded high root nitrogen in all the phases. The nitrogen content increased upto the 60th day and declined thereafter.

11. Leaf phosphorus content progressively declined from the 30th day to 120th and October sowing recorded an appreciable value. The root phosphorus content in October sowing was less in the initial phase and increased in the subsequent phases.

12. October sowing recorded high leaf potassium content and it was found to increase with the age of the plant. April and May sowing registered the least values. The root potassium content was high in April sowing and October sowing ranked next to it.

13. The reducing sugars, non reducing sugars and total sugars were high in October sowing. April and May sowing recorded low values. The glucose concentration in the reducing sugars was low in crops sown in October and November but the fructose concentration was high.

14. High crude fibre content was noted in April and May sowings and a low content was recorded in October, November and December sown crops.

15. The bitter principle content was high in roots harvested from October and December sowings and was low in the roots from June and July sowings.

16. The starch content was high in July sowing and was low in April and May sown crops.

17. The specific gravity of the chicory root infusion was high in the crop sown in October.

18. The leaf protein content was high in January crop. A moderate quantum of protein was noted in October, November and December sowings. Root protein was high in December, November and October sown crops.

19. The enzyme IAA oxidase was high in March to May sown crops and was low in October to December sown crops. The peroxidase activity showed a similar trend. The catalase activity was high in May and June sowings and was low in October to December sown crops.

20. Auxin activity was generally high in the leaves and roots of crops raised from September to December.

21. Leaf and root auxin content generally followed the same trend as was noted in auxin activity.

22. Leaf and root gibberellin activity was generally high in April and May sown crops and was low in October sown crop.

23. Gibberellin content followed the same general trend as in the case of gibberellin activity.

24. The cytokinin activity was high in the October, November and December sown crops at all phases of growth. Its activity was less in April, May and June sowings.

25. The cytokinin content paralleled the trend in its activity.

26. April, May and June sown crops showed high inhibitor activity and it was low in October to December sown crops.

27. The ABA equivalent was high in April to June sown crops and was less in October to December sown crops.

28. The number of bolted plants, crude fibre content, starch content, IAA oxidase in leaves and roots, peroxidase and catalase activity in the roots and the auxin and gibberellin content in the leaves and roots had positive relationship with photothermal unit. The other components had negative relationship with PTU.

II Stages of harvest

1. Leaf area and leaf number progressively increased upto 120 days.

2. The highest root length was noted on the 180th day and the highest girth on the 150th day. The girth/length ratio was high 105 days after sowing.

3. The highest mean weight of root was recorded on the 150th day. The mean weight of root beyond 120th day varied within narrow limits.

4. The fresh weight of tops and roots was high on the 120th day was less in subsequent stages. The top/root ratio was high in the early stages and the ratio was low on the 120th day.

5. Dry weight of tops and roots was high on the 120th day. Delayed harvest beyond 135th day resulted in decrease in the dry weight of the roots and tops. The highest harvest index was recorded on the 180th day.

6. NAR and RGR were high on the 120th day and gradually declined beyond the 120th day.

7. The leaf and root nitrogen was high in the early stages and decreased as the stage of harvest was delayed. The leaf and root phosphorus was high in the early stage and declined beyond the 120th day. The leaf potassium content was high upto the 90th day and declined thereafter. The root potassium was high on the 60th day and a declining trend thereafter was noted.

8. The starch granules accumulation in the top, bottom, and middle portion of the root was high on the 135th day. The starch accumulation was initiated only after 45 days.

9. The reducing, non-reducing and total sugars were high on the 120th day and were less in the subsequent stages. The fructose concentration of the reducing sugars was high on the 120th day. The glucose concentration of the reducing sugars showed an inconsistent trend.

10. The leaf protein was high on the 165th day whereas root protein was high on the 120th day. In the later stages, the protein content was reduced.

11. The leaf and root amino acids were found to increase from the 30th day and reached a peak on the 120th day. The amino acid histidine was present predominantly.

12. The specific gravity of the chicory root infusion was high in roots harvested on the 120th day. Its activity was very low in the early harvests but increased beyond 105th day onwards.

13. The enzyme IAA oxidase in the leaves and roots was high on the 60th day and 30th day respectively and there was sharp reduction in its activity later. The peroxidase activity was high on the 165th day and in the early stages its activity was low. The leaf and root catalase activity was high on the 30th day and was reduced in the subsequent stages.

14. High auxin content was noted on the 60th day in the leaves and 45th day in the roots and declined thereafter. The gibberellin content in the leaves and root was high in the early stages, gradually declined on the 120th day and there was an increase in the subsequent stages. The cytokinin content in the leaves was high on 60th day and in the root on the 120th day. The inhibitor content was high in the final stages of harvest.

15. All the growth and yield components showed positive relationship with root yield. Leaf and root nitrogen and phosphorus contents showed a negative relationship with yield. The tuber yield was positively correlated with quality

attributes and enzyme activity. A highly negative relationship with auxin content in leaf and root and positive association with leaf ABA was also noted.

III Effect of gibberellin and vernalisation on the chicory seed yield

1. A high percentage of germination, early flowering, greater plant height and high seed yield were recorded in the plants raised from seeds treated with GA at 500 ppm and vernalised for one day.

2. Plants raised from seeds treated with GA at 250 and 500 ppm and vernalised for 10 and 30 days showed no bolting. The fresh weight of the roots and dry matter production was high in the plants raised from seeds treated with GA at 500 ppm and vernalised for one day.

LITERATURE CITED

LITERATURE CITED

LITERATURE CITED

- Abdel Rahaman, M., T.H. Thomas, G.J. Dossand and L. Howell. 1973. Changes in endogenous plant hormones in cherry tomato fruits during development and maturation. Physiol. Planta. 34 : 39-43.
- Anderson, W.S. 1937. The progressive storage of starch in roots of the sweet potato during the growing season. Proc. Amer. Soc. hort. Sci. 32 : 713-715.
- Anon. 1950. The Wealth of India. A dictionary of Indian Raw Material and Industrial Products. Vol. II. The Council of Scientific and Industrial Research, New Delhi. pp.161-2.
- 1982. Weather at Tamil Nadu Agricultural University, Coimbatore in 1981. Annual report of the TNAU, Coimbatore.
- Arreguin.- Lozano, B. and J. Bonner. 1949. Experiments on sucrose formation by potato tubers as influenced by temperature. Physiol. Planta. 24 : 720-733.
- Badillo-Feliciano, J. and M.A. Lugo-Lopes. 1976. Effect of four levels of N, P, K and micronutrients on sweet potato yields. J. Agri. Univ. Puerto Rico 50 : 597-603.
- Bagchi, D.K. and S. Chanda. 1980. Note on the effect of age at harvest on root yield and extracted protein in beet root. Indian J. agric. Sci. 50 : 794-795.
- Bailey, L.H. 1942. The Standard Cyclopedia of Horticulture. The Macmillan Company, New York. pp.241.
- Beattie, J.H., V.R. Boswell and E.E. Hall. 1934. Influence of spacing and time of planting on the yield and size of sweet potato. USA Agric. Dept. Cir. : 327.

- Bhatia, I.S., S.K.Mann and R.Singh. 1974. Biochemical changes in the water soluble carbohydrates during the development of chicory. J. Sci. Pd. agric. 22 : 535-539.
- Eytan, I.G., B.Gur and A.H.Halevy. 1974. Further studies on the relationship between growth regulators and tuberization of dahlies. Physiol. Plants. 31 : 23-28.
- Block, K. 1958. Estimation of aminoacids by two dimensional chromatography and spectrophotometric methods. J. Biol. Chem. 225 : 1245-1254.
- Bodlaender, K.B.A. 1963. Influence of temperature, radiation and photoperiod on development and yield. In "Growth of the potato". J.D.Ivins and F.L.Milthorpe. Ed.P.199. Butterworth, London.
- Borah, M.N. and F.L.Milthorpe. 1967. Rep. Uni. Notts. Sch. Agric. In: Root Crops. L.A.Wilson. 1977. Ecophysiology of Tropical Crops. Ed.P.T.Alvin and T.T.Kozlowski. Academic Press, New York. pp.187-236.
- Bouniols, A. 1974. Invitro neoformation of inflorescence of buds from Cichorium intybus root segments; the influence of tissue hydration and the consequences for aminoacid composition. Plant Sci. 2 : 363-371.
- Brocklehurst, P.A. and J.Dearman. 1980. The germination of carrot seed harvested on two dates; a physiological and biochemical study. J. Exptl. Bot. 31 : 1719-1725.
- Bukovac, M.J. and S.H.Wittwer. 1958. Reproductive responses of lettuce to gibberellin as influenced by seed vernalisation, photoperiod and temperature. Prog. Amer. Soc. hort. Sci. 71 : 407-411.
- Caravaggi, A. and A.Manfredi. 1937. Laxative action of active principles extracted from some commonly used plants. Chem. Abstr. 31 : 4719.
- Chailakhyan, M.H. 1958. The effect of gibberellin on growth and development of plants. Bot. Gaz. 41 : 925-952.

- Chatterjee, B.N. and N.C.Mandal. 1976. Growth and yield of sweet potato in the Gangetic plains of West Bengal. J. Root Crops. 2 : 25-28.
- Chaurasia, B.D., S.S.Sirochi and J.S.Chohan. 1977. Effect of harvesting period on the growth and yield of chicory (Cichorium intybus L.). Indian J. agric. Sci. 42 : 115-6.
- Chapman, H.W. 1958. Tuberization in the potato plant. Physiol. Plants. 11 : 215-224.
- Chopra, S.L. and J.S.Kanwar. 1976. Analytical Agricultural Chemistry. Kalyani Publishers, New Delhi.
- Chouard, P. 1960. Vernalization and its relation to dormancy. Ann. Rev. Plant Physiol. 11 : 191-238.
- Chubey, B.B. and D.G.Dorrell. 1974. Jerusalem artichoke, a potential fructose crop for the prairies. Can. Instt. Fd. Sci. Technol. J. 7 : 98-100.
- Chubey, B.B. and D.G.Dorrell. 1978. Total reducing sugar, fructose and glucose concentrations and root yield of two chicory cultivars as affected by irrigation, fertilizer and harvest dates. Can. J. Plant Sci. 58 : 789-793.
- Curtis, D.S. and H.T.Chang. 1930. The relative effectiveness of the temperature of the crown as contrasted with that of the rest of the plant upon flowering of celery plant. Amer. J. Bot. 17 : 1047-1048.
- Davis, G.E. 1941. The effect of environmental factors on tuberization in wild potato Solanum demissum. Amer Potato. J. 18 : 226-269.
- Dienair, W. 1940. Physiologically active flavouring substances in nutrition and the possibility of chemically showing their presence. Chem. Abstr. 14 : 3391.

- Dinakaran, M. and D. Sundararaj. 1980. Preliminary studies on chicory (Cichorium intybus L). S. Indian. Hort. 8 : 23-27.
- * Delegher, V., W. Degreef, R. Dejaegere and L. Neirineckx. 1980. Variation in the content of mineral elements in the roots and leaves of witloof chicory. Bulletin de la société Royale de Botanique de Belgique. 119 (2) : 153-160. Hort. Abstr. 51 : 8531.
- Dekock, P.C., K. Commissiong, V.C. Former and R.H.E. Inkson. 1960. Inter-relationship of catalase, peroxidase, hematin and chlorophyll. Plant Physiol. 35 : 399-404.
- Doney, D.L., R.E. Wyse and J. Clair. 1981. The relationship between cell size, yield and sugar concentration of the sugarbeet. Can. J. Plant Sci. 61 : 477-483.
- Dorrell, D.G. and B.B. Chubey. 1977. Irrigation, fertilizer, harvest dates and storage effects on the reducing sugar and fructose concentrations of Jerusalem artichoke tubers. Can. J. Plant Sci. 57 : 591-596.
- Duncan, A.A., L.E. Scott and F.C. Stark. 1958. Effect of potassium chloride and potassium sulphate on yield and quality of sweet potato. Proc. Amer. Soc. Hort. Sci. 71 : 391-398.
- Edmond, J.P. 1971. Physiology, biochemistry and ecology of sweet potato - Production, processing and marketing. pp. 30-58.
- Enyi, B.A.C. 1972. Effect of shoot number and time of planting on growth, development and yield of cassava (Manihot esculenta Crants). J. hort. Sci. 47 : 457-466.
- Enyi, B.A.C. 1973. Growth, development and yield of some tropical root crops. Proc. Int. Symp. Trop. Root Crops. IIIrd. pp. 76-79.
- Fiala, V. and E. Jelivet. 1980. The aptitude of roots of Witloof chicory production by their carbohydrate composition. Scientia. Hort. 11 : 123-134.

- Forsline, P.L. and A.R. Langille. 1975. Endogenous cytokinins in Solanum tuberosum L. as influenced by photoperiod and temperature. Physiol. Plants. 34 : 75-77.
- Galston, A.W. and L.Y. Dalberg. 1954. The adoptive formation and physiological significance of indole acetic acid oxidase. Amer. J. Bot. 41 : 373-380.
- Goldwin, G.K. 1982. A technique for studying the association between components of the weather and horticultural parameters. Scientia Hort. 16 : 101-107.
- Gregory, L.E. 1956. Some factors controlling tuber formation in the potato plant. Amer. J. Bot. 43 : 281-288.
- _____. 1965. Physiology of tuberization. Encyclopedia of plant physiology. Springer Verlag, Berlin, Heidelberg, New York. 15 : 1328-1354.
- Halevy, A.H. and J. Brian. 1975. Hormonal regulation of tuberization in dahlia. Acta. Hort. 47 : 319-329.
- Harada, H. and J.P. Nitsch. 1959. Changes in endogenous growth substances during flower development. Plant Physiol. 34 : 409-415.
- Harrington, J.E. and L. Rappaport. 1957. Influence of gibberellins on stem elongation and flowering of anise. Sci. 125 : 601-602.
- Hartman, I.A. 1956. Some effects of temperature and photoperiod on flower formation in chicory. Bot. Gaz. 119 : 102-104.
- Haynes, P.A., J.A. Spence and C.J. Walter. 1967. The use of physiological studies in the agronomy of root crops. Proc. Int. Sym. Proc. Root Crops. Univ. West Indies. Section III, 1-17.
- Highkin, H.R. 1956. Vernalization in lettuce. Plant Physiol. 31 : 399-403.

- Humphries, E.C. 1956. Mineral components and ash analysis. Modern methods of analysis. Springer verlag. Berlin pp. 468-502.
- Hunt, L.A., D.W. Wholey and J.H. Cock. 1977. Growth physiology of cassava. Field Crops Abstr. 10 : 77-91.
- Ivins, J.D. and P.M. Bremner. 1966. Growth studies with sugarbeet crop. Agric. progr. 4 : 77-82.
- Jackson, M.L. 1962. Soil chemical analysis. Constable and Co. Ltd. London.
- Jensen, W.A. 1955. The histochemical localisation of peroxidase in roots and its induction by indole acetic acid. Plant Physiol. 30 : 426-432.
- * Kaufmann, F. 1965. The influence of sowing dates on the yield performances of chicory. Arch Gärten (1965) 13 : 15-25. Hort. Abstr. 35 : 7906.
- Khan, G., V.P. Kapoor and M.I.H. Farooqi. 1980. A note on the carbohydrate and protein content of gladiolus corms. Indian J. hort. 37 : 182-4.
- * Khitryut, L.A. 1975. The effect of temperature and root size on witloof chicory development. Referativno Zhurnal (1974) 11 : 55-56 Hort. Abstr. 43 : 5814.
- Kim, Y.C. 1961. Effects of thermoperiodism on tuber formation in Ipomoea batatas L. under controlled conditions. Plant Physiol. 36 : 680-684.
- Koller, D., A.M. Mayer, A.M. Poljskoff and S. Klein. 1962. Seed germination. Ann. Rev. Plant Physiol. 13 : 437-464.
- Kulandaivelu, R., A. Balasubramanian, S.P. Palaniappan and Y.B. Morachan. 1980. Weather at Tamil Nadu Agricultural University, Coimbatore in 1979. Madras agric. J. 67 : 345-349.

- Kulandaivelu, R. 1981. Weather at Tamil Nadu Agricultural University, Coimbatore in 1980. Madras agric. J. 68 : 200-204.
- Landsberg, J.J. and C.V. Cutting. 1977. Environmental effects on crop physiology. Academic Press, London. pp.87-98.
- Lane, J.H. and L. Edmon. 1923. Determination of reducing sugars by means of Fehlings solution with methylene blue as internal indicator. J. soc. chem. indias 13 : 32-37.
- Lang, A. 1957. The effect of gibberellin upon flower formation. Proc. Nat. Acad. Sci. 43 : 709-717.
- Lang, A. and E. Reinhard. 1961. Gibberellin and flower formation. Advan. Chem. Ser. 28 : 71-79.
- Lawrence, C.H. and W.G. Barker. 1963. A study of tuberization in the potato Solanum tuberosum. Amer. Potato J. 40 : 349-356.
- Lawrence, C.H. 1980. Phytochemistry. Narosa Publishing House, New Delhi. pp. 79-83.
- Leopold, A.C. 1964. Plant growth and development. Tata-McGraw Hill Publishing Company Ltd., New Delhi. pp.385.
- Leonard, D.A., W.S. Anderson and M. Gieger. 1949. Field studies on the mineral nutrition of sweet potato. Proc. Amer. Soc. hort. Sci. 53 : 387-393.
- Letham, D.S. 1968. A new cytokinin bioassay and the naturally occurring cytokinin complex. Biochemistry and physiology of plant hormones. Ed. T.C. Moore. Narosa Publishing House, New Delhi. 147-176.

- Loomis, W.D. and P.K. Stumpf. 1958. The special role of individual aminoacids in plant metabolism. Plant Physiol. 8 : 262-276.
- Loomis, R.S. and C.W. Bennett. 1966. Competitive relationship in virus infested sugarbeet field. J. Amer. Soc. Sugarbeet. Technol. 14 : 218-231.
- Loomis, R.S. and W.A. Williams. 1969. Maximum crop Productivity : An estimate. Crop Sci. 9 : 98-103.
- Loomis, R.S.; W.A. Williams and S.M. Ghesali. 1969. Growth and productivity of tapioca. Leaf characteristics and yield. Exptl. Agric. 5 : 183-194.
- Loomis, R.S. and L. Rappaport. 1976. Productivity of root crops. Proc. Inter. Soc. Trop. Root. Crops. 4th : 70-84.
- Lowe, S.B. and L.A. Wilson. 1974. Comparative analysis of tuber development in the sweet potato (*Ipomoea batatas* L) Tuber initiation, tuber growth and partition of assimilate. Ann. Bot. (London) (N.S.). 38 : 307-317.
- Lowry, O.H., N.J. Rose Brough., A.O. Farr and R.J. Ran Dell. 1951. Protein measurement with folin phenol reagent. J. Biol. Chem. 193 : 266-275.
- Mahadeviah, S. and N. Singh. 1964. Leaf protein from the green tops of *Cichorium intybus* L. Indian J. Exptl. Biol. 1 : 193-194.
- Mandal, R.C. 1978. Agronomy of root crops and tuber crops at ICRI (ICAR), Trivandrum, Memoirgraph. pp.29-32.
- Mandal, R.C. and K.D. Singh. 1971. Present status of tuber crops - progress in agronomic research and future prospects. All India workshop on tuber crops, Central Tuber Crops Research Institute, Trivandrum. pp. 18-21.

- Mani, S.N., B.P. Indira and R.C. Mandal. 1975. Studies on maturity index in Coleus parviflorus. J. Root Crops. 1 : 87-88.
- Masuda, Y. 1962. Effect of light on growth inhibitor in wheat roots. Physiol. Plants. 15 : 780-790.
- McCready, R.M., J. Ganguly., V. Silveela and H.S. Owen. 1950. Determination of starch and amylose in vegetables. Ann. Chem. 22 : 1156.
- * Meijgaard, D. 1963. Growing witloof chicory (Dutch). Publ. Ser. "Het Tuinbouwbedrijf in glaziers" 8 (1962). pp. 56. Hort. Abstr. 31 : 3090.
- Melanson, D. and A.J. Trewavas. 1982. Changes in tissue protein in relation to auxin induction of DNA synthesis. Plant Cell and Enviro. 5 : 53-64.
- Michael Sivetz, Ch.E. and D. Normalw Destosier. 1979. Coffee technology. AVI Publishing Company Inc., West Port, Connecticut. pp. 78-79.
- * Michniewicz, M. and Kamiensk, A. 1964. Flower formation induced by GA, Kinetin and Vitamin C treatment in cold requiring plant (Cichorium intybus L) grown under non-inducing condition. Naturwissenschaften (1964) 51 : 2956. Hort. Abstr. 31 : 6844.
- Milthorpe, F.L. 1967. Some physiological principles determining yield of root crops. Proc. Int. Sym. Trop. Root Crops. Ist. 1-19.
- Mitchell, J.W. and G.A. Livingston. 1968. Methods of studying plant hormones and growth regulating substances. Agriculture, Handbook No. 336 U.S. Dept. Agr. Beltsville. pp. 132-136.
- Moorby, L. and F.L. Milthorpe. 1975. Potato. In Evans, L.T. Ed. Crop physiology. Cambridge University Press, London, pp. 225-257.

- Moral, G. and R.H. Wetmore. 1951. Tissue culture of monocotyledons. Amer. J. Bot. 38 : 138-40.
- Moore, T.C. 1980. Biochemistry and physiology of plant hormones. Narosa Publishing House, New Delhi. pp. 34-61.
- Murakami, Y. 1970. New rice seedling test for gibberellin-micro drop method. Jap. Agric. Res. quart. 3 : 5-9.
- Muthuswami, S. 1968. Studies on some aspects of manuring radish (Raphanus sativus L). Dissertation submitted to the University of Madras for the degree of M.Sc.(Ag.) in Horticulture, Faculty of Horticulture. Post Graduate Training Centre, A.C. and R.I., Coimbatore.
- Muthuswami, S. and C.M. Pappiah. 1980. The culture of chicory. Seeds and Fares 4 : 33-35.
- Narasimha Rao, U. 1960. The chicory cultivation in India. ICAR, New Delhi.
- * Nishiuchi, H. 1953. Experiment of artificial tuberization of the root of sweet potato in a glass pipe by the temperature gradient referring to the effect of the temperature system and relation of the partial moisture to the tuberization. Bull. Naniya Univ B3 : 115-118. Hort. Abstr. 23 : 4364.
- Nitsch, J.P. and C. Nitsch. 1956. Auxin dependent growth of excised Helianthus tuberosus tissue. Amer. J. Bot. 43 : 839-851.
- Orchard, E.R. and Van Rooyen. 1953. Chicory production in South Africa - its agricultural and industrial aspects. Sci. Bull. 339. Union of South Africa.
- Palmer, C.E. and O.E. Smith. 1970. Cytokinin induced tuber formation on stolons of Solanum tuberosum L. Physiol. Plants. 21 : 599-606.

Panse, V.G. and P.V. Sukhatme. 1957. Statistical methods for agricultural workers. ICAR Publication. New Delhi.

* Pankov, V.V. 1976. The effect of potassium on the chemical composition and productivity of carrots. Referativnyi zhurnal 2 : 55-73. Hort. Abstr. 48 : 2471.

Pappiah, C.M. and S. Muthuswami. 1981. Effect of spacing, phosphorus and potassium on tuber yield of chicory (Cichorium intybus L.). S. Indian hort. 29 : 149-151.

Parthasarathy, K., D.R.C. Balu and P.S. Rao. 1970. Studies on sandal spur. VIII. Polyphenol oxidase activity and metabolism of sandal (S. album) in health and disease. Proc. Indian Acad. Sci. 72 : 277-284.

Perur, N.G. 1962. Measurement of peroxidase activity in plant leaf tissue. Curr. Sci. 31 : 17-18.

Plinik, W and G.J. Vervelde. 1976. Jerusalem artichoke (Helianthus tuberosus) as source of fructose, a natural alternative sweetener. A Acta in Pflanzenbau. Acta. Hort. 142 : 153-162.

Pucher, G.W., G.S. Leavenworth., W.D. Ginter and H.B. Vickery. 1948. Studies in the metabolism of crassulacean plants: the effect of temperature on the culture of leaves of Bryophyllum. Plant Physiol. 23 : 123-132.

Pushkaran, K., P.S. Nair and K. Gopan Kumar. 1976. Analysis of yield and its components in sweet potato (Ipomoea batatas L.). Agrl. Res. J. (Kerala) 14 : 153-159.

Radin, J.W. and R.S. Loomis. 1971. Polar transport of kinetin in tissues of radish. Plant Physiol. 51 : 348-357.

Railton, T.D. and P.F. Wareing. 1953. Effects of day length on endogenous gibberellin in leaves of Solanum elaeagnifolium L. Changes in levels of free acidic gibberellin like substances. Physiol. Planta 28 : 88-94.

- Rajmohan, K. and P. Sethumadhavan. 1980. Tuberization processes in coleus. National Seminar on Tuber Crops Production Technology. Tamil Nadu Agricultural University, Coimbatore. pp.193-194.
- Rappaport, L. and S.H. Wittwer. 1956. Flowering in head lettuce as influenced by seed vernalization, temperature and photoperiod. Proc. Amer. Soc. hort. Sci. 64 : 429-437.
- Rappaport, L. and S.H. Wittwer. 1965. Stimulation of flowering by vernalization of endive seedlings. A preliminary report. Proc. Amer. Soc. hort. sci. 75 : 438-439.
- Rutherford, P.P. and D.R. Bard. 1971. Water uptake and invertase, hydrolase activities and bitter principles induced in chicory root discs by treatment with various plant growth regulators. Phytochemistry 10 : 1631-1638.
- Rutherford, P.P. and A.E. Flood. 1971. Seasonal changes in the invertase and hydrolase activities of Jerusalem artichoke tubers. Phytochemistry 10 : 953-956.
- Saini, S.S. and M. Singh. 1978. Chicory perspectives in India: Seeds and Farms 4 : 34-45.
- Sakmi, N. 1955. The biochemical relationship between glycine and serine. In "Amino Acid Metabolism". Ed. Mc.Eiroy and B. Glass. John Hopkins Press, Baltimore. pp.659-683.
- Sampathkumar, B. 1979. Studies on the growth and development of sweet potato. M.Sc.(Ag.) thesis submitted to the Tamil Nadu Agricultural University, Coimbatore. (Unpublished).
- Sass, J.E. 1964. Botanical Microtechniques. Oxford-IBH Publishing Company, New Delhi.

- Scott, E. and Bouwkamp, J.C. 1975. Effect of chronological age and composition of raw and processed sweet potato. Hort. Sci. 10 : 165-168.
- * Seget, A.V. and P. Puhlik. 1967. Problem concerning the individual development of chicory. Ved. Pr. ustred Vyrsk, Ust rosti Vyrobv V. Prase Ruzhni (1966) 10 : 67-86. Hort. Abstr. 37 : 1017.
- Selvaraj, R. 1981. Nutritional studies in chicory. M.Sc.(Ag.) thesis submitted to the Tamil Nadu Agricultural University, Coimbatore. (Unpublished).
- Shanmugavelu, K.G., S. Thamburaj, A. Shanmugam and N. Gopalswamy. 1972. Studies on the effect of time of planting and type of planting materials on the yield of sweet potato (Ipomoea batatas L.). S. Indian hort. 20 : 55-58.
- Sharma, V.K. and S.S. Sirohi. 1981. Chicory for blending with coffee. Planters. J. and Agriculture 48 : 147-149.
- Sharma, R.C., J.S. Grewal and A.K. Sharma. 1978. Dry matter and nutrient accumulation in the potato as affected by fertilizer application. JIPA 5 : 56-63.
- * Sihachakr, D., L. Rossignol, M. Rossignol and J.L. Prioul. 1982. Analyse de la tuberization chez la patate douce (Ipomoea batatas Lam) a partir de boutures deuilles. Physiol. vegetale. 20 : 53-57. Hort. Abstr. 54 : 3113.
- Sirohi, S.S. and N. Suryanarayana. 1970. Studies on the effect of different dates of sowing and seed rates on the growth and yield of chicory (Cichorium intybus L.). J. Res. 7 : 42-44.
- Simmonds, P.L. 1964. Coffee and chicory. Span. 16 : 26-28
Buchlersburg, London.
- Singh, R. and I.S. Bhatia. 1970. Study of the carbohydrate of chicory (Cichorium intybus L.). Maryana. Agric. Univ. J. Res. 1 : 1-9.

- Singh, H.R. 1971. Research work done on tuber crops (other than potato) in Uttar Pradesh. All India workshop on tuber crops. Central Tuber Crops Research Inst. Trivandrum. pp.67-69.
- Snedecor, G.W. and W.G. Cochran. 1967. Statistical methods. 6th Edition. Oxford and IBH Publishing Company, Ethen press, Calcutta.
- Spaldon, E. and A. Krausko. 1963. A contribution to the study of the influence of sowing date on the yield of chicory. Rostlinna vyroba (1962) 8 : 839-54.
Hort. abstr. 33 : 3043.
- Stoddart, J.L. 1959. The effects of gibberellic acid upon growth habit and heading in late flowering red clover. J. agric. soc. 52 : 161-167.
- Sundararaj, J.S., K.K. Ananthanarayanan and S. Muthuswami. 1969. Present status of tuber crops research in Tamil Nadu and scope for future lines of work varietal improvement. Indian Council of Agricultural Research workshop on tuber crops research. Ludhiana. pp.64-67.
- Sundara Raj, D. and G. Thulasidas. 1976. Botany of field crops. MacMillan & Co. India Ltd., India.
- Suzuki, M. and J.A. Cutcliffe. 1981. Sugar and eating quality of Rutabagas. Can. J. Plant. Sci. 61 : 167-169.
- Tanaka, Y. and D.I. Langerah. 1976. Effect of irradiation on quality and enzyme activities of chicory. J. Ed. Tech. 10 : 415-425.
- Tappan Dutta. 1971. Present position and immediate programme of tuber crops research in Assam. All India Workshop on Tuber Crops. Central Tuber Crops Research Institute, Trivandrum. pp.112-114.

- Thiagarajan, V. 1969. Studies on the response of Koorka (Coleus parviflorus Benth.) to graded doses of fertiliser application. M.Sc.(Ag.) Thesis, University of Kerala. (Unpublished).
- Thomas, H.T. 1981. Seed treatments and techniques to improve germination. Scientia Hort. 32 : 47-49.
- Thulasidas, G. and J.Chandra Mohan. 1964. Chicory a supplementary cash crop. Indian Fmg. 14 : 9-10.
- Togari, Y. 1950. A study of tuberous root formation in sweet potato. Bull Nat. Agric. Exp. Stn. (Tokyo). 68 : 1-96.
- Torrey, J.G. 1965. Root hormones and plant growth. Ann. Rev. Plant. Physiol. 16 : 435-459.
- Tsuno, Y. and K.Fujise. 1965. Studies on the dry matter production of sweet potato. Bull. Nat. Inst. Agric. Soc. (Japan). Ser. D. No.13 p.131.
- Uexkull, H.R.V. 1965. Problems in development of modern tropical agriculture. Proceedings Japanese Potassium Symposium. pp.63-64.
- Ulrich, A. 1952. The influence of temperature and light factors on the growth and development of sugar beet. Agron. J. 44 : 66-73.
- * Valette, R. 1981. Germination of Witloof chicory seeds at different temperatures. Bruxelles Revue de l'Agriculture. (1981). 34(4) : 995-1007. Hort. abstr. 52 : 2148.
- * Van Hossin, R. and E.Anderson. 1965. The influence of sowing date on bolting and yield of chicory. Ptsch Gartenwirt. (1964) 12 : 142-144. Hort. abstr. 34 : 6840.

- Vardjan, M. and J.P. Nitsch. 1961. Auxins and cytokinin in the growth and development of chicory. Bull. Soc. Botany. France. 108 : 363-374.
- Vasanthakumar, K. and E. Chacko. 1980. Propagation of medicinal yam (Dioscorea floribunda Mart. and D. composita. Hensl. by vine cutting. Proc. National Seminar on Tuber Crops, Tamil Nadu Agricultural University, Coimbatore. pp.163-171.
- Venugopal, K., A. Shanmugam and R. Shanatha. 1975. Sweet potato yield as a function of certain climatic parameters. Madras agric. J. 62 : 521-523.
- Verma, G.H.L., G.N. Agarwal, G.N. Singh and H.N. Pandey. 1969. Effect of time of planting on the yield of tubers in sweet potato. Indian Council of Agricultural Research Workshop on Tuber Crops Research, Ludhiana. pp. 89-92.
- Vijayakumar, T.M. 1982. Studies on the growth and development of coleus (Coleus parviflorus L. Benth. M.Sc.(Ag.) Thesis submitted to the Tamil Nadu Agricultural University, Coimbatore. (Unpublished).
- Waelsch, H. 1952. Certain aspects of the intermediary metabolism of glutamine, asparagine and glutamic acid. Adv. Enzymol. 13 : 237-239.
- Wallace, D.H., J.L. Oxman and H.M. Munger. 1972. Physiological genetics of crop yield. Advance. agron. 24 : 97-146.
- Wareing, P.F. and T.A. Villers. 1961. Plant growth regulations. Iowa State Uni. Press. p. 95
- Wareing, P.F. and I.D.J. Phillips. 1978. The control of growth and differentiation in plants. Pergamon Press, Oxford. pp.156.

- Wassink, E.K. 1953. Starch conservation in leaves of Helianthus tuberosus (L) and Helianthus annuus (L). Preliminary observations. Acta. Botan (Neerl) 2 : 37-45.
- Watson, D.J. 1958. The dependents of netassimilation rate on leaf area index. Ann. Bot. (London), 22 : 37-45.
- _____. 1972. Growth and productivity of tapioca III. crop ratio, spacing and yield. Exptl. Agric. 8 : 15-23.
- Went, F.W. 1957. The experimental control of plant growth. Chronica Botanica Co., Waltham, Mass. pp.343.
- Whyte, R.C. 1968. Crop production and environment. Faber and Faber, London. pp.89.
- Wilson, L.A. 1969. Alternative interpretations of a critical experiment in the physiological determinants of sweet potato. Biol. J. 3 : 29-38.
- Wilson, L.A. 1977. Root crops. In "Ecophysiology of tropical crops". Ed. P.T. Alvim and T.T. Kozlowski Academic Press, New York. pp. 187-236.
- Wittwer, S.H. 1956. The effect of gibberellin on economic crops. Econ. Bot. 12 : 213-255.
- Wittwer, S.H. and M.J. Bukovac. 1957. Gibberellin effects on temperature and photoperiodic requirement for flowering of some plants. Sci. 126 : 30-31.
- Zeevaart, J.A.D. 1968. Climatic control of reproductive development Ch. 16. In "Environmental control of plant growth". Ed. L.T. Evans. Academic Press, New York and London. pp. 289-310.

* Not seen in original

