QUANTITATIVE AND QUALITATIVE CHANGES IN COLEUS (*Solenostemon rotundifolius* (Poir) J.K. Morton) TUBERS DURING DEVELOPMENT AND STORAGE

By

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THESIS

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DECLARATION

I hereby declare that the thesis entitled **"Quantitative and qualitative changes in coleus (*Solenostemon rotundifolius* (Poir) J.K. Morton) tubers during development and storage"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

Certified that the thesis entitled "**Quantitative and qualitative changes in coleus *(Solenostemon rotundifolius* (Poir) J.K. Morton) tubers during development and storage**" is a record of research work done independently by Mr. A. Ramesh, under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to him.

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We, the undersigned members of the advisory committee of Mr.A.Ramesh, a candidate for the degree of Master of Science in Horticulture with major in processing technology, agree that the thesis entitled "**Quantitative and qualitative changes in coleus *(Solenostemon rotundifolius* (Poir) J.K.Morton) tubers during development and storage**" may be submitted by Mr.A.Ramesh, in partial fulfilment of the requirement for the degree.

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A.Ramesh

Dedicated to

My loving

Parents - Grandparents

&

Brothers & Sisters

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ABBREVATIONS

DM	-	Dry matter
TDM	-	Total dry matter
PPO	-	Poly phenol oxidase
POD	-	Peroxidase
DAT	-	Days after transplanting
DAS	-	Days after storage
DAP	-	Days after planting
Fwb	-	Fresh weight basis
RH	-	Relative humidity
t/ha	-	tonnes/ hectare
KMS	-	Potassium meta bisulphate
ERH	-	Equlibrium relative humidity
%	-	Percentage
PLW	-	Physiological loss in weight
cm	-	Centimeter

INTRODUCTION

1. INTRODUCTION

Coleus (*Solenostemon rotundifolius* (Poir) J.K. Morton) (Chinese potato) belongs to the family labiatae with its unique flavour, is a delicacy for many. As a crop, coleus can be accommodated both in the rice based cropping system and in the homestead based cropping system. Coleus demands less care and gives good yield. The crop is gaining popularity as a profitable enterprise. With yield potential of 10-15 tonnes per hectare and premium price in the early market, the crop has very good commercial potential. It also has the comparative advantage in management with low incidence of pests and diseases. Coleus is available in the market during the September- January in kerala. The crop from neighbouring states comes to the market during November- January and sometimes later also.

Coleus is harvested at different stages of maturity depending on the market trend. Thus the earliest crop produced is in the rice field, which is often harvested before full maturity reach the market by September.

Storability of the produce is poor due to spoilage, sprouting and weight loss. Methods to extent the storage life and minimize the post harvest losses will be useful to make the produce available for extended periods and also to overcome the market glut. Harvest of the produce at the ideal stage of maturity and its proper handling and storage are important factors to be considered.

Minimal processing in order to offer convenience for the consumers and conversion to dehydrated product to enhance storage are also options available.

Development of viable technologies for these are essential, for full exploitation of the commercial prospects of the crop.

The present study was undertaken with the following objectives.

- To analyse changes in quantitative and qualitative characters of coleus tubers during development.
- To analyse changes in quantitative and qualitative characters of coleus tubers during storage.
- To examine the storage characters of minimally processed tubers.
- To examine the storage characters of dehydrated tubers.

Review of Literature

2. REVIEW OF LITERATURE

Coleus botanically known as *Solenostemon rotundifolius* (Poir) J.K. Morton *(syn.Coleus parviflorus* chev and perrot*)* is an important tuber crop grown extensively as a vegetable. Coleus is an annual herbaceous plant with succulent prostrate or ascending stem with thick aromatic leaves. The plant bears a cluster of dark brownish heteromorphous tubers, which used as vegetable. The characteristic aroma of the tubers gives coleus a special place in the south Indian dishes. It is known as 'Chinese potato', 'Country potato' or 'hausa potato' in English and as '*koorka*' in Malayalam. Coleus tubers are rich in carbohydrates (18-21%) but low in proteins (1- 1.5%), calcium, iron and vitamins like thiamine, riboflavin, niacin and ascorbic acid are also present in small quantities. The tubers are used in curry preparations in the same way as potato. (Mohankumar *et al.* 2000). Coleus takes about five months after planting in the main field to mature and yield ranging from 10 to 15 t ha^{-1} is obtained.

2.1 TUBER INITIATION, DEVELOPMENT AND MATURITY

Information on tuber development, growth pattern, dry matter partitioning and other aspects in coleus are meager. In this section literature available on important tuber crops are reviewed.

Singh *et al.* (1973) found that, the early cultivars of potato bulked up rapidly up to 80 days after planting, while late varieties like Kufri Shindhur and Kufri Chamatkar bulked steadily up to 100 DAP (Days After Planting). Singh (1977) reported that the number of potato tubers produced increased with an increase in the age of crop.

Sowrokinos (1973) related the concept of physiological maturity of the potato to the stage when 97 per cent of the final tuber size and starch content is reached. Photosynthetic rate and tuber growth rate were highest during flower bud formation to flowering stages. (Puzina *et al.*, 1998). Fontes and Finger (1999) reported that the high temperature and low radiation were the principal factors limiting potato production and reducing tuber formation.

In cassava, starch deposition was preceded by secondary growth in the stelar region. Three weeks after planting, secondary growth started in roots. At this phase the roots were only 10 days old and starch grains were not conserved in the roots. However, by 26th day, starch deposition was observed in secondary xylem, which consists of massive xylem parenchyma, vessels and fibres. This massive secondary xylem formation followed by starch deposition represents tuber initiation (Indira and Kurian, 1977).

Maini *et al.* (1977) studied maturity index in cassava by recording the tuber yield and carbohydrate content of tubers and found that the carbohydrate content showed a decline from the mature stage.

Significant differences in the tuber-bulking rate among cassava genotypes were noticed and the peak bulking period under rain fed condition was during the sixth to the seventh month (CTCRI, 1982). The steep fall in tuber bulking rate is always linked with leaf shedding due to moisture stress, which is the major constraint to achieve the potential yield of cassava.

Ramanujam (1991) studied the tuberization in cassava under Kerala conditions; the tuber-bulking rate started increasing from 4th month onwards. While the higher peak tuber-bulking rate was found during 6-7th month, a second peak with lower bulking rate was found at 11th month of crop growth. In cassava, plant dry biomass was found to increase up to 8th month and it decreased between 8th and 9th month. The tuber DM was also maximum at 8th month after planting. Photosynthetic rate and tuber yield was maximum at 8th month and thereafter the rates declined. The retention of the crop up to 12 months did not significantly increase the tuber yield (Ravi, 2000).

Seven cultivars of sweet potato were studied for their tuber initiation and subsequent rate of development after planting for initiation and from 60th day up to 120th days after planting for development of tubers. It was observed that the early tuberisation variety matured late where as late tuberisation variety matured early, indicating that the early tuberizing variety need not be always early maturing types (Ramanujam and Indira, 1979). In sweet potato, early maturing short duration cultivars exhibited fast bulking of tubers whereby yield reached a maximum within a growing period of 12-16 weeks. The daily bulking rate varies between 1.8-7.3 g/plant on dry weight basis (Indira and Ramanujam, 1985). The tuber-bulking rate showed a positive correlation with rainfall and relative humidity (Chowdhury, 1994).

The wetland taro reaches maturity earlier under non-flooded conditions when compared to flooded conditions and in the latter, the corms are immature even in the tenth month stage (Ching, 1970). Shallow flooding (or) irrigation up to soil saturation hastened the maturity of wetland taro (Pena and Malchor, 1983). The specific gravity of 1 to 1.1 for main corm and 1.1 to 1.58 for sucker corms were considered optimum to determine the stage of harvest of wetland taro (Ezumah and Plucknett, 1973).

2.2 NUTRIENT MANAGEMENT AND PRODUCTION TECHNOLOGY

Coleus thrives well in tropical and sub tropical regions. A well-drained medium fertile soil is suitable for it's cultivation. The vine can be planted in the main field on ridges at 30 cms apart between the month of July and October. It required 10t of FYM and 30, 60, 50 kg of NPK per ha (KAU, 1996)

Thyagarajan (1969) observed that application of nitrogen at 30 and 60 kg per ha resulted in significant increase in the yield of tubers and the response was linear, while the levels of P and K had no significant effect on yield. Studies with six levels of nitrogen from 0 to 100 kg per ha in coleus at CTCRI (1969) showed that the tuber yield increased significantly up to 60 kg per ha. Harish and Mohankumar (1976) suggested a fertilizer dose of 80:60:80 kg N, P_2O_5 and K_2O for coleus with full does of P and half dose of N at the time of planting and the remaining half dose of N and K six weeks after planting along with interculture and earthing up.

Rajmohan and Sethumadhavan (1980) suggested an application of 10 tonnes of farmyard manure with a fertilizer dose of 180 kg urea, 380 kg super phosphate and 140 kg murate of potash (80:60:80 N, P_2O_5 and K_2O per ha) with half of N and K and full dose of super phosphate as basal at the time of planting and the remaining half N and K six weeks after planting. It has been observed that raising the levels of Nitrogen from 40 to 80 kg had significantly increased the tuber yield in coleus.

Geetha (1983) studied the nutritional management in coleus and it was observed that yield increased by increasing levels of nitrogen up to 120 kg per ha, and it was further observed that split application of N and K increased the yield by 2.72 tones per hectare over basal application. Another study by Kabeerathumma *et al.* (1985) showed that for the production of 25.74 tonnes of coleus tuber, the crop removed 106.7 kg N, 13.23 kg P and 107.44 kg K per hectare.

Spacing cum manurial trial on Coleus conducted at the Regional Agricultural Research Station, Pilicode (KAU, 1979) indicated that the fertilizer requirement of this crop is governed to a very large extent by the spacing adopted. The optimum spacing was found 60 cm ×15 cm. The optimum requirements of N and K were 80 kg each per hectare. Investigations were undertaken to study the influence of types of cuttings on growth and development of coleus by Vijaykumar and Shanmughavelu (1984). They observed that the terminal cuttings were the best for planting and it will increase the number of tubers, length, girth and weight of the tubers.

2.3 DRY MATTER PARTITIONING IN TUBERS

The proportion of total dry matter in the tubers, of all the cultivars, increased as maturity progressed. Purohit *et al.* (1970) studied distribution of fresh and dry weight in leaves, stem and tubers in seven Indian potato cultivars. They reported that accumulation of dry matter was more in shoots till the initiation of tuber enlargement phase and it declined thereafter. The relationship between tuber size and dry matter content is not linear (Ifenkwe *et al.*, 1974). Variation in dry matter accumulation in potato tubers has been reported by Ezetiel (1990). It ranged from 74-80 per cent in summer and 67-97 per cent in autumn at 80 days after planting in four cultivars studied.

Enyi (1973) using three cultivars in cassava showed that most of the dry matter produced was diverted into the stem and root tubers and the proportion of the DM diverted into the leaf decreased with time. The partitioning of dry matter for the growth of shoot and tuber was found to be linear and there was a high positive correlation between the total biomass and the dry matter accumulation in shoot and tuber (Ramanujam and Lakshmi, 1984).

In cassava, a significant difference in partitioning of DM for tuber growth was found among the cultivars tested, which varied from 0.32-0.7 per unit of total dry matter produced. The short stature cultivar CI-590 was more efficient in utilizing about 70 per cent of total DM for tuber growth whereas the profusely branching cultivars CE-22 and H-1423 accumulated greater DM (52.6-64.2%) in shoot resulting in lower harvest index. Hence, profuse branching is not a desirable character for high tuber yield (Ramanujam, 1985). Pattern of dry matter accumulation in cassava under rain fed and irrigated conditions was studied by Nayer *et al.* (1986) which revealed that supplementary irrigation provided during dry spell promoted total biomass production and accumulation of dry matter in the storage roots.

In cassava, during the first three months of growth, the dry matter accumulation was more in leaves when compared to stems and tuberous roots. After the third month, more dry matter was being accumulated in the tuber than the rest of the plant parts (Ramanujam and Birader, 1987). The total biomass production of cassava at 4th and 6th month of crop growth showed significant positive correlation with tuber yield. Therefore, it is suggested that large number of cultivars can be screened for their high yield potential between 4th and 6th month after planting instead of evaluating at 10-12th month which is time consuming (Ramanujam, 1991).

Studies on DM production in 14 cultivars of cassava revealed that DM in shoot and root continuously increases with the advancement of crop age. During the initial three months of growth DM accumulation was greater in leaves than in stems or tuberous roots. However, after the third month, DM accumulation was greater in the tuber than other plant parts. The tuber growth rate exceeded the shoot growth rate around third month and this was considered as the start of rapid tuber bulking phase. After the onset of tuber bulking the weight of dead and senescing leaves was greater than active leaves (Ramanujam, 1991).

Agata (1982) observed in sweet potato a sigmoid curve on total dry weight and reported the highest biomass yield of 20.5 t/ha in about five months. While there was decrease in vine weight towards harvest, the tuber weight increased linearly with the age of the crop (Indira and Ramanujam, 1985). Dry matter partitioning in sweet potato depends upon the cultivar, location, climate, day length, soil type, incidence of pest and diseases and cultivation practices (Bradbury and Holloway, 1988). In sweet potato the leaf dry matter ranged from 12-14 per cent (Candlish *et al.*, 1987).

Mannan *et al.* (1992) studied the growth and distribution of dry matter in leaves, stem and tubers of two sweet potato varieties (Kamalasundari and Daulatpuri) at 7 stages of harvest. The first harvest was done at 30 DAP (Days After Planting) and subsequently at 20 days interval terminating at 150 days. It was observed that there is a decrease in the proportion of leaves and stems in the total dry matter and a concomitant increase in the total dry matter with in time. Total dry matter production and efficiency of dry matter (DM) allocation to tubers is an important factor determining tuber yield. The increase in TDM as well as tuber dry matter follows a sigmoid pattern in sweet potato. There may be a linear increase in TDM and tuber DM (Nair and Nair, 1995).

The effect of potassium nutrition on dry matter accumulation of sweet potato at different stages of plant growth was studied by Mukhopadhyay *et al.* (1999), the dry matter accumulation in leaves increased up to 90th day, while in shoot and tuber it increased gradually up to 150 days after planting.

Ravi *et al.* (2000) reported that sweet potato exhibits three growth phases based on dry matter partitioning. During the first phase, shoot growth dominates with an increased proportion of DM diverted to shoot growth. This is followed by a second phase of constant partitioning of DM between shoot and tuber growth. During the third phase, a major portion of DM is partitioned to tubers.

Studies with respect to dry matter production and partitioning were done by Sobulo (1972). The study revealed that in *Dioscorea rotundata*, the total dry matter production remained slow until 4th month and there after increased steadily up to 9th month and declined towards the end of10th month. The dry matter production of shoot (stem and leaves) was slow until fourth month and thereafter increased up to 6th month. Between 6th to 10th months, the leaf dry matter production gradually decreased. The stem dry matter production remained more or less constant between 6th to 9th months and then declined at 10th month. Okoli (1980) found that in *Dioscorea rotundata* and *Dioscorea alata,* the dry matter production was slow up to 3 ½ months and increased drastically at 4th month and thereafter decreased gradually towards the end of 7 ½ months. Tuber initiation started by 3 ½ months and the dry matter accumulation in tuber increased steadily up to 7 ½ month and then declined. Studies by choudhury *et al* (1999) revealed that the crop growth rate (CGR or Dry matter Production Rate) remained very low up to three months and during this period there was no significant difference in dry matter production rate among the species. From 4th month onwards, the CGR increased steadily and the rates differed among the species.

Partitioning of dry matter significantly differed among different species of *Dioscorea*. In *Dioscorea alata* and *Dioscorea rotundata,* up to 4th month, about 30 per cent of total dry matter was diverted to canopy development. The allocation of dry matter towards shoots coinciding with an active tuber bulking. In contrast, *Dioscorea esculenta* showed greater portion of dry matter was diverted towards tuber growth. Short photoperiod induced more tuberization at the early growth phase (Okezie *et al* .1987)

Studies on the dry matter accumulation of *Amorphophallus companulatus* at the different stages of growth were conducted at CTCRI, Trivandrum. The results indicated that the dry matter in the above ground portion increased up to 6th month and then decreased till harvest. In the underground portion the dry matter accumulation increased up to 10th month (harvest) and it was reverse order in roots (Nair and Mohankumar, 1991).

Sivan (1979) recognized three growth phases of taro under dry land conditions. Phase-I lasted for about 1.5 to 2 months and during this period both the leaf and corm dry matter decreased. Phase-II represented grand growth period and the plants accumulated dry matter very rapidly reaching a peak during 5.5 to 6 months. Rapid increase in corm dry matter started about two months after planting and the corm continued to develop. Increase in leaf dry matter was rapid than the increase in corm dry matter during this phase. Root dry matter increased steadily during phase-I and phase-II and reached it's peak at about 6th month. From about 6th month onwards, phase-III was recognized during which total plant dry matter declined. Leaf dry matter decreased very rapidly and levelled off at very low values after onemonth. The corm DM continuously increased up to 10-11.5 months. Mohankumar and Sadanandan (1989) studied the growth and dry matter accumulation in taro (*Colocasia esculenta* L. Schott) as influenced by N P and K nutrition. The results revealed that tuber and total dry matter production increased significantly up to 80 kg N and 100 kg K_2O ha^{-1}.

Wilson (1984) found the highest leaf growth in tannia between 4.5 and 6th month of growth. Maximum leaf dry weight and LAI occurred at 5.5 to 6.5 months and the plant height was maximum at about 7th month. After 7th month, leaf dry weight, LAI and plant height declined until harvest at 10th month. Accumulation of dry matter in the central corm began at about three months after planting and corm weight increased rapidly until 7th month.

2.4. BIOCHEMICAL CHANGES DURING DEVELOPMENT OF TUBERS

Christensen and Madsen (1996) studied the changes in potato starch quality parameter during development of potato tuber. It was revealed that glucose-6-phosphate and granule size significantly increased. Appeldoorn *et al.* (1999)

found that the enzyme Glucose-6-phosphate decreased after onset of tuberisation in potato. Change in carbohydrate metabolism during the initial stage of potato tuber formation was analysed by Helder and Vreugdenhil (1999). They stated that glucose and fructose levels decreased significantly upon tuber formation by a change in sucrose hydrolysis.

Long (1978) reported that in the pulp of cassava contain the carbohydrate in the range of 74.77 to 87.91 percent and the peel contains 34.66 per cent.

Mukhopadhyay *et al.* (1999) reported that starch content in tuber increased with the age up to 150 days after planting in sweet potato. Rooted cuttings had more starch content (69.41 to 72.40%) than fresh vine (68.79 to 69.27%). Prathibha *et al.* (1995) studied the enzyme inhibitors in tuber crops and their thermal stability in several tuber crops and found that coleus tuber possessed higher amylase activity.

Sugar content of potato tubers were found to decline from the tuber initiation to full maturity (Burton and Wilson, 1970) and this sugar content during tuberisation and the time of lifting is largely dependent on variety (Sowokinons, 1973). Tamate and Bradbury (1985) reported that considerable variability in total sugars of sweet potato exists even within different roots of the same cultivar. Time of harvest had a significant effect on total sugar content in six cultivars grown in one location in Brazil (Menezey *et al.*, 1976). Sugar content of coleus was studied by Vijayakumar and Shanmugavelu (1985). They observed that the total sugar content increased gradually and reached a peak at 120th day and there after declined. They attributed this to progressive increase of starch in tubers.

Changes in phenolic acid concentration during development of coloured potato tubers were studied by Lewis *et al.* (1999). They observed the phenolic acid levels were about twice those of the anthocyanins and reached their maximum at a slightly lower tuber weight than anthocyanin and flavonoids.

2.5 CHANGES DURING STORAGE OF FRESH TUBERS

Tubers are living organisms and as such are subject to losses during their autonomous life i.e., after the tuber has been separated from the plant. This is because the life processes require energy and the tuber has to supply thus from its own reserves. During storage, there is a continuous weight loss and changes in chemical composition, which may adversely affect its quality, depending, on the duration and condition of storage. Good storage can merely limit storage losses in a good product over relatively long periods of storage.

2.5.1 PLW (physiological loss in weight)

Weight loss is a quantitative loss, which ultimately affect the marketability of the tubers. Several factors like water loss, pest and disease incidence and sprouting contribute to the weight loss. Smith (1933) found that potatoes harvested at immature stage lost 9.89 per cent in weight during 7-month in storage, whereas potatoes harvested when mature, lost 6.97 per cent in the same period. Butch baker *et al.* (1973) reported that the age of tubers and temperature were highly correlated with weight loss.

Kaul and Sukumaran (1984) observed that the weight loss of potato tuber could be less in evaporative cold storage when compared to control. The physiological loss in weight of potato tubers was studied under natural storage condition for 180 days with tubers of different size. The result showed that the weight loss of tubers increased gradually with storage period and it was inversely proportional to the tuber size (Hossain *et al.*, 1998).

The PLW of various cultivars of potato stored in gunny bags at ambient conditions indicated that the PLW of the potato tubers increased with increasing storage period in all the cultivars. (CSHAU, 2002). The minimum physiological weight loss was observed in potato cv. Kufri Chandramukhi followed by cv. Kufri Jawahar under different storage method (cold storage, diffused light storage) while cv. Kufri Badshah had highest weight loss (Patel *et al.*, 2001). Sharma (2001) reported that the physiological loss in weight of hybrid potato was increased with increasing storage period at room temperature. Storage behaviour of seven advanced potato hybrids stored for four months at ambient temperature at Modipuram in Western UP revealed that ambient stored potatoes had lowest PLW when compared with room temperature (Singh et al., 2001).

Cassava tubers stored under vacuum desiccators (temperature 23.8 to 27.8°C and 100 per cent RH) showed less physiological loss in weight compared to those stored under wooden chamber (temperature 23.8°C to 27.8°C and 86 to 100 per cent RH) (Raja *et al.*, 1978). Sreemulanathan *et al.*, (1980) studied the efficacy of wooden chamber and vacuum desiccators as storage containers for cassava. They found that weight loss could be reduced from 8.2 per cent under ambient conditions to 3.1 per cent in wooden chambers and 0.58 per cent in vacuum desiccators.

Storage studies conducted at International potato center (CIP) (Dayal *et al.*, 1990) showed that the weight loss of sweet potato roots stored for 30 days could be reduced from 25.73 to 7.94 per cent by storing the roots in sand. After 60 days storage, the weight loss was 41. 96 per cent under ambient conditions of storage as compared to 16 per cent under storage in sand, (Ambient storage- tubers filled in nylon bags and hung from the ceiling under diffused light conditions)

Weight and moisture loss during the storage of *Dioscorea rotundata, Dioscorea alata* and *Dioscorea esculenta* was compared at 29°C and 70 per cent relative humidity (Hariprakash and Nambisan, 1996). It was observed that the percentage of weight loss was high in *Dioscorea esculenta* (31.7 per cent) when compared to other two species.

2.5.2 Sprouting during storage

Sprouting of tubers can result in relatively high weight losses. Pushkarnath (1976) studied the sprouting initiation under varying temperature for potatoes stored at 5, 10, 15 and 20°C. Sprout initiation occurred at 30, 15, 8 and 5 weeks respectively.

Effect of storage temperature on the potato was studied by Wurr and Allen (1976) and they found that the storage period of 14 days at 2 to 3°C, followed by storage at 15.6°C was favourable for sprouting. Rastovski and Van *et al.* (1981) reported that the length of dormancy period and sprouting behaviour during storage depend on the variety and storage conditions such as temperature, humidity of the storage atmosphere, light, oxygen concentration, carbon dioxide concentration and the possible presence of volatile substances from the potato tuber.

Banerjee (1994) studied the sprouting behaviour of seven selected potato cultivars at room temperature in polythene bags. He observed that the rate of spouting was highest in cv. Kufri Jeevan and lowest in Kufri Sindhuri. Dhital *et al.* (1997) observed from their experiment that potato tubers stored in a rustic store (mean daily temperature 9.5°C) with diffused light or in a glass house (mean temperature 16.2°C) in darkness or diffuse light did not affect storage physiology, but warmer storage decreased dormancy and increased sprouting.

Effects of storage temperature on the sprout characters of potato tubers were studied by Chousoo and Young (1997) by storing them at temperature of 4,8 and 12°C. The result indicated that storage at 12°C produced the highest number of sprouts per tubers. Fontes and Finger (1999) reported that low temperature (4-5°C) storage delay the sprouting up to 10 months.

Gangro *et al.* (2000) conducted a study to find out the influence of tuber weight and sprouting of seed potato cv. Desiree. The study revealed that as tuber weight increased sprouting time decreased. Sprout growth during CA storage (5% CO_2, 18-20°C and 90-95 per cent RH) were studied in potato varieties Kufri Chandramukhi and Kufri Jyothi. These were compared with control (tuber stored in the BOD incubator maintained at 18-20°C and 90-95 per cent RH). The results indicated that the number of sprouts per tuber, sprout weight and sprout volume 60 DAS were significantly higher under CA storage. (Singh and Ezekiel, 2001)

A study conducted on storage of yam tubers under ambient condition showed that sprouting appeared after 10-15 days of storage in *Dioscorea rotundata* but only after 70 days of storage in the case of *Dioscorea alata* and *Dioscorea esculanta*. Sprout growth was rapid in *Dioscorea alata* and *Dioscorea esculenta*. (KAU, 1987).

2.5.3 Spoilage during storage of tubers

Curing of potato tubers after harvest by incubation at 28.0°C to 32.0°C at a relative humidity of 85.0 to 90.0 per cent for two weeks was found to prevent rotting (Wilson *et al.*, 1977). Bhatnagar and Gupta (1979) reported that 3-10 per cent of the cold stored potatoes were spoiled due to rotting, cold injury etc. Invasion of microorganism into the potato tubers may cause considerable losses due to diseases. The diseases which develop during storage are late blight, early blight, dry rot, skin spot, black rot, silver scurf, soft rot (Nagaich *et al.*, 1982). The stem end area of potato tubers were found more prone to black spot disease compared to other parts (Hironaka *et al.*, 1998).

Alauddin *et al* (1991) conducted experiments in potato and found that lack of oxygen during storage cause a physiological disorder of tubers and 18-20.9% oxygen is thought to be ideal for storage. Low temperature and high RH resulted in minimum losses due to plant pathogens during storage and a temperature of 37.4° F and 85-90% RH are recommended.

Biological methods have been found to be the most promising techniques for suppressing the microbial spoilage of potatoes during long-term storage by Sinirnova (2000) and found that a liquid culture of antagonist bacteria treated potatoes did not suffer dramatically. Verma *et al.*, (2001) categorized the spoilage micro flora, which cause spoilage of the potato. They include *Rhizopus* sp., *Pencillum* sp., *Aspergillus* sp., *Alternaria* sp., *Bacillus* sp., *Clostridium* sp., *Micrococcus* sp., *Enterobacter* sp. and other unidentified gram positive and gram-negative bacteria and fungi.

Cassava roots cannot be kept in fresh state for more than a few days after harvest. Changes, which occur during storage, are thought to be caused either by pathogens or by physiological reactions (Booth, 1975). Pencillium and yeast species have been found to be associated with rotting of cassava tubers (Amla and Sankar, 1975). The predominant rotting organisms for cassava in India are *Rhizopus oryzae* and *Bacillus* species. Both are capable of causing root discoloration and increased acidity (Balagopal *et al.*, 1980).

Raja *et al.* (1978) reported that cassava tubers show better resistance to spoilage when stored in modified environment (wooden chamber, vacuum desiccators) compared to control. Sreemulanathan *et al.,* (1980) compared the spoilage within the modified (vacuum desiccators and wooden chambers) environment condition. It revealed that almost 100 per cent spoilage occurred after 12 days in vacuum desiccators while 35 per cent tubers only were spoiled in 15 days when stored in wooden chambers.

Prasad *et al.* (1981) studied the post harvest loss in sweet potato in relation to common method of storage *viz.*, room space and a ventilated closed yard space. The result showed that the loss due to storage rot was comparatively higher in room space (33.9 per cent) than in tubers stored in ventilated yard space (20.8 per cent).

Chilling renders sweet potato roots more susceptible to attack by microorganisms such as fungi, perhaps through an increased sensitivity of the tissue to pathogenic pectic enzymes and to a reduced capacity for synthesizing phytoalexins (Arine and Smith, 1980).

Karuri and Hagenimana (1995) made observation on 31 sweet potato clones under natural storage condition. Visual examination of edible part in stored roots showed that varieties KEMB7, KEMB9, KEMB10, KEMB20, KEMB24, KEMB37, KSP20 and KSP119 were acceptable and did not rot after five weeks of storage in saw dust under ambient air conditions.

2.5.4 Biochemical changes during storage of tubers

Khurana *et al.* (1985) reported a marked decrease in the starch content of potato tubers during the first 60 days of storage in a cold store (or) at room temperature followed by additional decrease in the next 60 days. The starch content decreased from 66.3 per cent (on dry weight basis) at the time of storage to 55.8 under cold store condition and 55.1 per cent at room temperature conditions after a period of 60 days.

Activities of starch degradation enzymes were studied during the storage of potatoes by Biemelt *et al.* (2000). It was found that no significant change occurred in most of the enzyme activity during storage but with the onset of sprouting β-amylase activity increased two fold and α-amylase increased 80 per cent.

Maini and Balagopal (1978) reported that there was a reduction of starch content during storage of cassava tuber. Analysis of stored, unspoiled cassava tubers showed a slight reduction of starch up to a level of 3.9 per cent, where as in spoiled tubers it was to the extend of 21.7 per cent from the original value of 81.5 per cent. This could be due to enzymatic damage of starch (Raja *et al.*, 1978).

Changes in carbohydrate constituents of *Dioscorea.* spp. stored at 29°C and 70% RH were studied by Hariprakash and Balanambisan (1996). A decrease in starch content (40 per cent reduction after 90 days in *Dioscorea esculenta*) was the most significant change observed. More than 50 per cent of the reduction in starch took place during the dormancy period.

Samotus *et al.* (1974) reported that sugar formation in a number of Poland varieties of potato stored at 1, 2 and 6°C for 18 to 22 weeks was correlated with variety. Extensive investigations have been conducted at CPRI for about two decades on the changes in sugar content of potatoes during storage by Verma *et al.* (1974). A increase in the sugar content of different potato varieties stored at low temperature (3-5°C). Sweetness of potatoes increased when they are stored at comparatively low temperature because of accumulation of reducing sugars and sucrose (Pushkarnath, 1976). Workman *et al.* (1976) found that storage of potatoes at temperature of 0 to 5°C caused an increase in sugar accumulation.

Kaul and Sukumaran (1984) reported that the pattern of sugar accumulation in potatoes stored under evaporative cooled storage was similar to that observed in potato stored at high temperature. The magnitude of sugar accumulation was lower and an increase in the total and reducing sugar content of potatoes stored at low temperature (2-3°C) was observed by Khurana *et al.*, 1985. Changes in fructose and glucose in tubers stored at 3-4° (or) 7-10°C have been monitored (CPRI, 1988). It has been observed that both fructose and glucose content increased in potatoes stored at either temperature, though greater increases occurred in potatoes stored at 3-4°C.

Smith (1987) studied the phosphorylase enzyme activities during cold storage of potatoes and found that it catalysed the breakdown of starch and caused accumulation of sugar in potatoes stored at 4.4°C. Investigation at lower temperature storage have shown that there was a marginal increase in the reducing sugar content of potato stored for 5 months at 18-20°C, though sucrose content increased considerably (Uppal and Verma, 1987). However, it was reported that very little change in the sugar content of potatoes occurred if they were stored for nine weeks at 18-20°C (Marwaha *et al.*, 1990).

Storage temperature and physiological age of the potato tuber was found to cause sweetening (Burton, 1989). Oberien and Morrissery (1989) reported that in potatoes, reducing sugars are involved in the non-enzymatic browning reaction.

Uppal and Verma (1990) have observed about 60 percent increases in sugar content in potato during the first 30 days of storage at 3-5°C.

Changes in reducing sugars and sucrose content during storage of potatoes were studied by Pinto and Pinto (1993) at 1°C (or) 8°C for 30, 60 (or) 90 days then reconditioned at 20°C for 10 days. They reported that the different temperature regimes had no influence on change in sugar content. Zrenner *et al.* (1996) reported that the cold storage of potato tubers is known to cause accumulation of sugars.

Biochemical and physiological changes in potato tubers were analysed at on set of dormancy and during storage at 23°C and 3°C by Espen *et al.* (1999). The result showed that during storage at 23°C the uptake of sucrose increased concomitant with tuber sprouting. At 3°C, levels of reducing sugars and sucrose were found increased. Sugar accumulation during storage at 5 per cent CO_2, 18-20°C temp and 90-95 percent RH were studied in potato varieties Kufri Chandramukhi and Kufri Jyoti at CPRI, Shimla. The study revealed that reducing and total sugar content increased after 60 days of storage as compared to control (Singh and Ezekiel, 2001).

The storage of sweet potato cultivar Filipino in ambient conditions of 28-32°C and 66-83 per cent relative humidity for 17 days resulted in increase of total sugars, sucrose, glucose and fructose (Kawabata *et al.*, 1984).

Potato tuber contains a number of phenolic compounds such as scopoletin, trijosine, chlorogenic, coumaric and caffeic acid (Uppal and Verma, 1982).

Tripathi and Verma (1975) reported a decrease in the content of total phenols in the peels and pulp of two varieties of potato stored under ambient conditions. Uppal *et al.* (1978) reported an increase of about 100 per cent in the content of total phenol in tubers of four varieties of potatoes stored for about 5 months either under ambient conditions or in a cold store.

Evaluation of seven Indian potato varieties and five exotic cultivars for important desirable processing traits before and after 75 days of storage under two higher temperatures was done by Marwaha (2000). He reported higher tuber dry matter content and lower non-enzymatic and enzymatic discoloration, reducing sugars and phenolic compounds.

Marriot *et al.* (1978) studied the discoloration of cassava tubers in storage. The injured tubers of cassava facilitate entry of oxygen leading to increased activity of PPO and hence faster streaking.

The changes in total phenol content were studied in six varieties of cassava up to six days of storage (Rickard, 1981). It was found that for all varieties, there was a decrease in total phenol content during the second day of storage. When rotting and pathogen attack were initiated on the fourth day the phenol content was increased. Total phenols showed an initial reduction when cassava tubers were stored followed by an increase up to fifth day and again followed by a reduction (Balagopalan and Padmaja, 1985). They also estimated the activities of polyphenol oxidase (PPO) and peroxidase (POD) in deteriorating cassava tubers up to five days of storage under ambient conditions. It was found that these activities were triggered in deteriorating cassava tubers within 24-48 hrs of storage.

Cassava varieties H 1687, M4 and H 2304 were stored in pit and changes in the biochemical constituents like starch and sugar were analysed at weekly intervals up to eight weeks. The result indicated that as the number of weeks of storage increased the starch content decreased, but sugar content increased (Balagopalan and Padmaja, 1985).

The phenol content of Irish potato and sweet potato was studied by Adelusi and Ogundana (1978), who reported that there was initial decrease in the levels of phenols followed by a gradual increase till the end of the incubation period. Sweet potato infected with *Rhizopus oryzae* exhibited nearly five times more phenol accumulation compared with the uninfected tubers (Ray, 1997).

2.6 MINIMAL PROCESSING OF VEGETABLES

Horticultural products are prepared and handled to maintain their fresh nature while providing convenience to the user. Minimal processing of horticultural products involves cleaning, washing, trimming, coring, slicing, shredding and packaging with out killing the tissues (Sheafelt, 1987). Other terms used to refer to minimally processed products are 'lightly processed', 'partially processed', 'fresh processed' and 'pre-prepared'. Such a product with living plant tissues is washed, given preservation treatment and packaged before distribution, so chance of microbial contamination is very less (Cantwell, 1992). Minimally processed vegetables have certain advantages like convenience in use, supply in ready to cook form, reduction in size, which enables easy handling and transportation (Siriphanich, 1993). The most important factor with regard to minimally processed fruits and vegetables is the maintenance of a high level of quality for an adequate duration subsequent to harvest (Gertmenian, 1992). Schtimme (1995) reported that minimally processed vegetables are living tissues that undergo catabolism and respiration. Consumption of minimally processed vegetables has increased due to benefits of their convenience and freshness to the consumers (Huxsoll and Bolin, 1989). Minimal processing of fresh horticultural products is an expanding consumption trend for fruit and vegetables (Wiley, 1994).

The microbial quality of minimally processed vegetables is also influenced by unit operations such as peeling, cutting and washing. Slicing fresh vegetables causes many physiological and microbial changes that influence quality and shelf-life (Rolle and Chism, 1987; Watada *et al.* 1990).

Romig (1995) reported that cultivars with reduced key enzyme activity are desired for minimal processing. Minimal processing accelerates physiological changes and promotes growth of spoilage microorganisms (Abvenainen, 1996).

Fresh, minimally processed produce can be enrobed in edible materials providing semi permeable barrier to gas and water vapour. Such coatings can reduce respiration and water loss and used for carriers of preservation and antioxidants (Bladwin *et al.*, 1999). Minimal processing of vegetables induced stress and undesirable metabolic changes that reduce the product shelf life in relation to the intact vegetables. The metabolic changes include increase in respiration and transpiration rates, pathological breakdown, synthesis of secondary compounds and membrane lipid breakdown (Lana, 2000).

Breadfruit was minimally processed and half of the quantity was blanched (5 seconds at 100°C) and the remaining was unblanched and stored at three temperature regimes like 0°C, 5°C and 8°C. The study revealed that marginal changes occurred in the chemical composition of the breadfruit slices irrespective of blanching and venting over the entire storage period. Storage at 0°C exhibited chilling injury (Crane *et al.*, 1998).

Klein (1987) found that the difference in rate of water loss between intact and wounded plant surface varied from 5 to 10 fold for organs with lightly suberised surface (carrot, parsnip) and 500 fold for heavily suberized potato tubers. Li-paiyin and Barth (1998) reported that carotene retention was 15 per cent greater in edible-coated carrots than in the control.

Adams *et al.* (1989) reported that much of microorganism and debris liberally coated in the surface of unwashed lettuce were removed by washing with tap water. Peeling and cutting on the other hand may enhance the contact between a contaminated plant part and other tissue, and make vegetables susceptible to microbial proliferation.

Minimal processed lettuce shows an exponential increase in PPO (polyphenol oxidase) enzyme activity, which in turn causes browning. (Cantos *et al.*, 2000). Biochemical and microbial changes during the storage of minimally processed cantaloupe melon cv. Mission was determined at 4 and 20°C. The study revealed that changes in most of the biochemical parameters with storage time were relatively slow at the lower temperature than 20°C (Lamikanra *et al.*, 2000).

2.7 STORAGE OF DEHYDRATED TUBERS

The removal of water from the products before marketing may be referred to as dehydration or drying (Setty *et al*, 1978). Dehydration is one of the methods of preservation of surplus produce, which will minimize the fluctuation in market price during storage (Sakhale *et al*, 2001)

Sugar contents of potatoes have a very important role in determining the colour of the fried products (chips). Out of all the sugars, glucose and fructose (reducing sugars) are the important ones, as they react with amino acids to produce non-enzymatic discoloration in chips during frying at high processing temperature (Marwaha, 1997)

Enzymatic discoloration takes place when potatoes are cooked. It developes in peeled or cut potatoes, when they are exposed to air for a short time. It is generally accepted to be the result of tyrosine-tyrosinase reaction with the ultimate formation of a black pigment melanin (Marwaha, 1997). Schaller and Amberger (1974) have shown that enzymatic discoloration of potatoes depends not only on tyrosine and polyphenol oxidase, but also on total phenol content, amino acids, dry matter content, chlorgenic acid and flavonols. Enzymatic discoloration is of great significance in pre- peeled potatoes or sun-dried potatoes, to prevent this, peeled or cut potatoes should be dipped in 0.1-0.2% sodium bisulphite for five minutes or in 0.5% Sodium Meta bisulphite for five minutes or in 0.5% Sodium bisuphite solution for ten minutes (Marwaha, 1997)

In the Central Food Technological Research Institute, Mysore (1976) studies were conducted on the potato varieties for making dehydration of dices. Varieties like 'Kufri Chandramukhi'and 'Kufri Kuber'and hybrids C-990 and VB-8 were found most suitable for making dehydrated dices and a solar tent and trays were fabricated for dehydrating potatoes in different forms. Potato slices, sewai, granules and papads were the dried products, which after frying in the oil were found acceptable. The dried product had a self-life of six months, when packed in low-density polythene bags.

Waghmare *et al.,* (1999) studied effect of Tertiary butyl hydroquinone (TBHQ) on shelf life of potato chips. Shelf life of chips prepared from variety Kufri Jyothi was increased from 45 to 60 days, where as chips prepared from Kufri Chandramukhi showed shelf life from 30 to 45 days.

Equlibrium relative humidity of tutifrutti candy was analyzed by Dabdade and Khedkar (1982) by Winks Weight method. It was revealed that the optimum relative humidity for storage of tutifrutti was 51 per cent. Mould growth was observed above 70 percent RH with eight days. The moisture sorption isotherm studies of osmotic dehydrated carrot shreds were studied by Hardeep Singh (2001). The study revealed that the dehydrated carrot shreds were more hygroscopic. Dehydrated samples required a lower RH for safe storage.

Studies on storage and dehydration characteristic of 7-onion cultivars were done by Sakhale *et al.* (2001). They reported that the cultivar 'Deco' and 'Jalgalon white' scored maximum for overall acceptability, colour, taste and texture, which were indicative of their better suitability for dehydration and also rehydration.

Sensory qualities of pre treated, dehydrated cauliflower were studied by Srivastava and Sulebele (1975). They found the dark brown colour was high in untreated sample compared to treated one and also the other characters like texture, flavour were inferior in un treated compared to treated.

Effect of dehydration and storage of cauliflower on the physical characters were studied by Kaur and Singh, (1981). They found that colour and flavour on reconstitution in sulphited product was not in an acceptable range because of poor colour, flavour and the reconstitution ratio decreased with the advancement of storage period.

Materials and Methods

3. MATERIALS AND METHODS

The investigation on quantitative and qualitative changes in Coleus tubers during development and storage was carried out in Regional Agricultural Research Station, Pattambi and College of Horticulture, Kerala Agricultural University, Vellanikkara from May 2001 to October 2002. A total of four experiments were conducted as detailed below.

3.1 CHANGES DURING DEVELOPMENT OF COLEUS TUBERS

Field experiments were carried out using two varieties namely 'Sreedhara' and 'Nidhi' and one advanced culture of coleus namely 'CP-74'. Raised beds of size 6 x 1 m were prepared and cuttings planted in three rows, following 30 x 20 cm spacing. The experiment was laid out in RBD with six replications. The crop was raised as per the practices recommended by the Kerala Agricultural University (KAU, 1996) (plate 1)

In order to assess the quantitative and qualitative changes during development of tubers and to quantify the various parameters, 10 randomly selected healthy plants from each replications were uprooted and observations on roots, stem, leaf, tubers (if any) were recorded as given below.

3.1.1 Total biomass

The total biomass was recorded as weight of the whole plant.

3.1.2 Economic biomass

Dry weight of tubers (if any) at each stage of growth was recorded separately as economic biomass.

3.1.3 Dry matter partitioning

For determining the dry matter partitioning a weighed quantity of the whole plant was separated into different plant parts (stems, leaves, tubers, roots) and

Plate 1. View of Coleus in field.

dried in hot air oven at 60°C till two consecutive weights agreed, proportion of dry matter in each part of the plant at each stage of growth was recorded.

3.1.4 Days to maturity and maturity indices

Days to maturity and maturity indices were recorded by the number of days from the date of planting, visual and physical characters, *viz*., peel colour, flesh colour, tuber length, tuber girth, maximum diameter and peel thickness.

3.1.4.1 Length

The length of tuber was measured from the base to the apex using a vernier and recorded in centimeter.

3.1.4.2 Girth

The maximum girth was measured using a non-elastic twine and centimeter scale.

3.1.4.3 Number of tubers

Total number of tubers per plant was recorded.

3.1.4.4 Maximum diameter

Tuber diameter was measured using a vernier caliper.

3.1.4.5 Peel thickness

Peel thickness of the tubers was measured using a screw gauge.

3.1.4.6 Peel percentage

Peel percentage by weight was calculated by peeling 100 gm of tubers.

3.1.5 Specific gravity

Volume was measured by water displacement method and weight to volume ratio was calculated.

3.1.6 Tuber colour

Tuber colour was recorded based on visual assessment.

3.1.7 Sensory quality

Sensory evaluation of coleus tubers were studied to assess the colour, appearance, texture, aroma, mouth feel (taste), and over all acceptability. A panel of 10 judges evaluated the tubers using a nine-point scale.

Quality grades	Score
Like extremely	9
Like very much	8
Like moderately	7
Like slightly	6
Neither like nor dislike	5
Dislike slightly	4
Dislike moderately	3
Dislike very much	2
Dislike extremely	1

3.1.8 Starch content

Starch content of tubers harvested at different intervals was estimated by hydrolysing starch into simple sugars and measuring the quantity of simple sugar colorimetrically. The sample was treated with 80 per cent alcohol to remove sugar and then the starch was extracted with 52% perchloric acid. The starch was then hydrolysed to glucose and dehydrated to hydroxy methyl furfural. This compound formed a green coloured product with anthrone and it was read at 630 nm. Starch content was expressed as percentage to the total dry weight (Sadasivam and Manikham, 1992).

3.1.9 Soluble Sugars

Sugar content of tubers harvested at different intervals was estimated using the procedure as described under 3.1.8 using the alcohol extract.

3.1.10 Polyphenols

Variation in polyphenol content in tubers during development was estimated using Folin-ciocalteu reagent. Weighed samples were extracted with 80 per cent alcohol repeatedly and the alcohol was evaporated completely. The residue was then dissolved in known volume of water and aliquots from the extract were used for colour development by adding folin-ciocalteu reagent followed by twenty per cent sodium carbonate. The blue colour developed was read at 650 nm in a spectrophotometer (model Spectronic, 2000) with reagent blank. A standard curve was prepared using catechol (Malik and Singh, 1980).

3.1.11 Quality parameters of nematode infested tubers

Nematode infested tubers were collected from the field during the final harvest stage and the quality parameters *viz.*, starch, sugars and polyphenol were estimated as described under 3.1.8, 3.1.9 and 3.1.10.

3.2 QUANTITATIVE AND QUALITATIVE CHANGES IN COLEUS TUBER DURING STORAGE

In order to study the quantitative as well as qualitative changes in coleus tubers during storage, fully matured, freshly harvested tubers from variety *'Nidhi'* were collected and stored in four different storage temperature regimes as given below.

1.Storage at room temperature (28±2°C)

2. Storage at zero energy cool chamber(plate 2)

3. Storage at 8-10°C

4. Storage at 0°C (deep freezer)

Plate 2. View of zero energy cool chamber.

Plate 3. Coleus tubers stored under zero energy cool chamber.

Under each storage temperature regime one kg of tubers in two replications stored adopting three methods.

1. In gunny bags
2. In polythene lined gunny bags
3. In open conditions (trays)

In addition one kg of tubers in two replicates were also stored in pits (diameter 30 cm, depth 45 cm). The pits were covered with mud pot (plate 4). Observations on various parameters were recorded prior to storage and subsequent observations at fifteen days intervals till the samples lost marketability. The observations recorded are given below.

3.2.1 PLW (physiological loss in weight)

Weight of fresh tubers was recorded immediately after harvest and subsequent reduction in weight was recorded at fifteen days interval, as long as the tubers remained in the marketable stage. Tubers were declared unmarketable when more than 20 per cent of tubers exhibited symptoms of decay, mould growth, sprouting or shriveling.

$$PLW = \frac{\text{Initial weight - final weight}}{\text{Initial weight}} \times 100$$

3.2.2 Sprouting

The sprouting percentage was calculated by number of tubers sprouted in one kg of tubers and expressed in percentage.

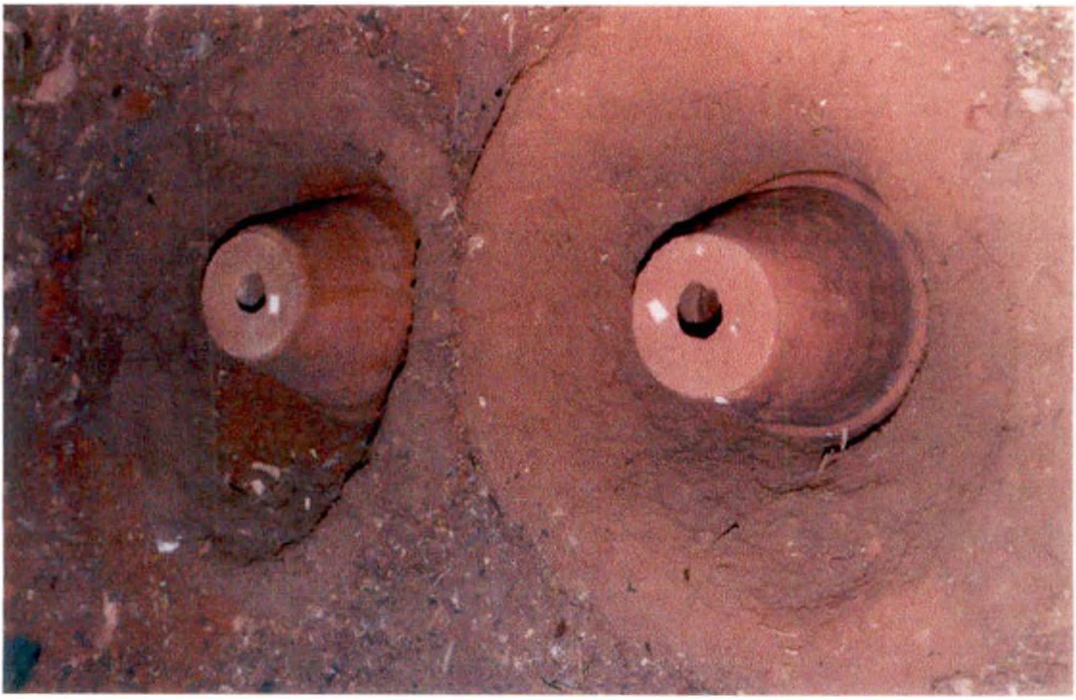

Plate 4. Coleus tubers stored under pit.

3.2.3 Spoilage

One kilogram of tubers was subjected to storage in different conditions. The number of the spoiled tubers was recorded once in fifteen days intervals during storage period. These observations were continued till 20 per cent of tubers were found spoiled and expressed in percent basis.

3.2.4 Colour

The change in colour during storage was recorded based on visual observation.

3.2.5 Starch

Starch content of the stored coleus tubers was estimated by the procedure as described under 3.1.8.

3.2.6 Sugar

Sugar was estimated as described under 3.1.9.

3.2.7 Polyphenols

Polyphenol content of the stored sample was estimated as described under 3.1.10.

3.2.8 Ease of peeling

Five tubers were selected at random from each of the storage treatments and adopting a scoring method as given below.

Very easy	1
Easy	2
Moderate	3
Difficult	4
Very difficult	5

3.2.9 Sensory quality

Sensory quality of stored coleus tubers was observed by following the procedure as described under 3.1.7.

3.3 QUALITATIVE CHANGES OF MINIMALLY PROCESSED COLEUS TUBERS DURING STORAGE

Freshly harvested tubers var. Sreedhara was used for this experiment with the following steps.

1: Peeling: Complete removal of skin (Epidermal layers) from the tubers.
2. Peeling followed by blanching in hot water for 2-3 minutes.
3. Peeling followed by steeping in potassium Meta bisulphite (blanching time and temperature, concentrations of KMS fixed based on the preliminary trial).

The peeled tubers were steeped in potassium metabisulphite solution. The concentration, time and temperature were standardized based on preliminary trial as detailed below.

Concentration of KMS	Time (minutes)	Temperature (°C)
2.5 g/l	5, 10, 15	60, 80, 90
5.0 g/l	5, 10, 15	60, 80, 90
7.5 g/l	5, 10, 15	60, 80, 90

One kilogram of tubers from each of the treatments were taken in polyethene bags and stored under three temperature regimes with three replicates.

1. Zero energy cool chamber
2. At 8-10°C
3. At room temperature

The observations were recorded on recovery of processed product, spoilage percentage, greening if any and colour development.

3.3.1 Recovery of processed product

Recovery after minimal processing was recorded as

$$\text{Recovery (\%)} = \frac{\text{Final weight}}{\text{Initial weight}} \times 100$$

3.3.2 Spoilage (%)

Weights of the tubers were recorded at daily interval during storage period until 20 per cent of tubers were found spoiled. Spoilage was expressed as percentage of weight.

3.3.3 Greening/colour development

Greening and colour changes in minimal processed tubers were observed on visual basis.

3.4 QUANTITATIVE AND QUALITATIVE CHANGES DURING STORAGE OF DEHYDRATED COLEUS TUBERS

The peeled sliced tubers were dehydrated to 10 to 12 per cent moisture and stored under ambient conditions. The following parameters were recorded.

3.4.1 Dehydration methods

3.4.1.1 Moisture

Moisture content of the dehydrated samples was estimated gravimetrically by drying the sample in a hot air oven at 70°C±1 for two days. Drying was repeated till the sample attained constant weight. Moisture content was expressed in percentage (Ranganna, 1977).

3.4.1 2 Sun drying

Ten kilograms of tubers were peeled, sliced and subjected to drying. During the night hours, the samples were covered using polybags and kept inside the room to prevent the reabsorption of moisture. The drying was carried out until constant weight was recorded in two consecutive observations.

3.4.1.3 Hot air drying

Ten kilograms of tubers were peeled sliced and dried in hot air oven at 60°C, the weight was recorded on three hours interval. The drying process was continued until the constant weight was recorded.

3.4.2 Storage conditions

The dried tubers obtained from above dehydration methods were stored in gunny bags and polythene lined gunny bags. Five replications of the following types of samples were stored.

T_1 - Sun dried tubers stored in gunny bag

T_2 - Sun dried tubers stored in polythene lined gunny bag

T_3 - Hot air oven dried tubers stored in gunny bag

T_4 - Hot air oven dried tubers stored in polythene lined gunny bag

The following observations were recorded.

3.4.2.1 Driage

Driage was calculated as percentage from the difference in weight.

$$\text{Driage (\%)} = \frac{\text{Initial weight - final weight}}{\text{Initial weight}} \times 100$$

3.4.2.2 Spoilage

Spoilage was recorded as number of days of storage till 20 per cent of samples were found spoiled.

3.4.2.3 Rehydration ratio

Rehydration ratio of dehydrated samples was determined by rehydrating the samples (10 g) for ten minutes in boiling water (100 ml). Rehydration ratio was calculated from the weight of dehydrated samples and weight of the rehydrated samples (USDA, 1944).

3.4.2.4 ERH (Equilibrium Relative Humidity)

Five-gram samples of the dehydrated material were placed in preweighed petridishes and kept in desiccators. The moisture content of the sample was taken by drying in a oven at 70°c.The desiccators were exposed to 40,60 and 80 percent relative humidity with the help of different strength (36.38,27.7 and 17.5 ml in 100ml of distilled water respectively) of sulphuric acid. Then the desiccators were sealed air tight and kept in room at 25°C. Gain/loss of weight was taken until the two consecutive weight obtained with 24 hours interval. The equilibrium relative humidity of dehydrated samples was determined by Graphical Interpolation Method suggested by Ranganna (1977).

3.4.2.5 Sensory quality of rehydrated materials

Sensory quality of rehydrated material was evaluated as described under in 3.1.7.

3.5 STATISTICAL ANALYSIS

Statistical analysis was performed using MSTAT -C package available at the central computer facilities at the Department of Statistics, College of Horticulture, Vellanikkara. The data were analysed appropriately either as RBD or CRD using the standard statistical procedure as per Panse and Sukhatme (1978).

Results

4. RESULTS

Results obtained from various experiments conducted under the study are presented in this chapter.

4.1 GROWTH PATTERN AND DRY MATTER PARTITIONING IN COLEUS

4.1.1 Total fresh biomass

Changes in total biomass from 60 days after transplanting (DAT) till harvest is presented in Table 1 and Fig 1. The fresh weight increased from an average 390 g per plant at 60 DAT to 539 g per plant at 90 DAT stage in the variety 'Sreedhara'. In the variety 'Nidhi,' fresh weight increased from an average 373.5 g per plant to 446.33 g per plant and in CP-74, it increased from 360.83 g per plant to 395 g per plant at 75 DAT stage. From 90 DAT stage, there was a decline in total biomass accumulated. In the variety 'Sreedhara,' fresh weight decreased from 539 g per plant at 90 DAT to 53.5 g per plant at harvest stage (150 DAT). In 'Nidhi' the fresh weight decreased from 446.33 g per plant to 59.17 g per plant at harvest stage. In culture CP-74 also a decrease of fresh weight was recorded from 395 g per plant to 60 g per plant at harvest stage. The absolute growth rate was highest between 75 and 90 DAT in varieties Sreedhara (7.98 g per plant per day) and Nidhi (3.37 g per plant per day) (Table 1a and Fig 1a) whereas in culture CP-74, it was maximum between 60 and 75 DAT.

4.1.2 Fresh weight of Leaf

The ratio of leaf biomass in terms of fresh weight to total biomass during different stages of growth is given in Table 2 and Fig 2. At 60 DAT, leaves constituted 41.04 per cent in variety 'Sreedhara', 42.48 per cent in 'Nidhi' and 49.98 per cent in culture CP-74. The leaf fresh weight decreased to 2.65 per cent in variety 'Nidhi' and 9.39 per cent in variety 'Sreedhara' at 135 DAT stage and was negligible at 150 DAT stage.

Table 1. Biomass accumulation in coleus at different stages of growth

Variety	Total Biomass (g/plant)						
	Stage of Development (Days after transplanting)						
	60	75	90	105	120	135	150
Sreedhara	390.0	419.17	539.0	475.17	403.67	267.17	53.5
Nidhi	373.5	395.83	446.33	422.33	405.33	205.0	59.17
CP-74	360.83	395.0	364.5	355.17	351.33	154.83	60.0
CD(0.05%)	NS	NS	NS	76.66	NS	46.28	NS

Table 1a. Absolute growth rate of total biomass at different stages of growth

Variety	Absolute growth rate (g/plant/day)					
	Stages of development (Days after transplanting)					
	60-75	75-90	90-105	105-120	120-135	135-150
Sreedhara	1.94	7.98	-4.26	-4.77	-5.90	-3.20
Nidhi	1.36	3.37	-1.60	-1.13	-6.97	-6.39
CP-74	2.28	-2.03	-0.62	-2.66	-5.47	-7.63

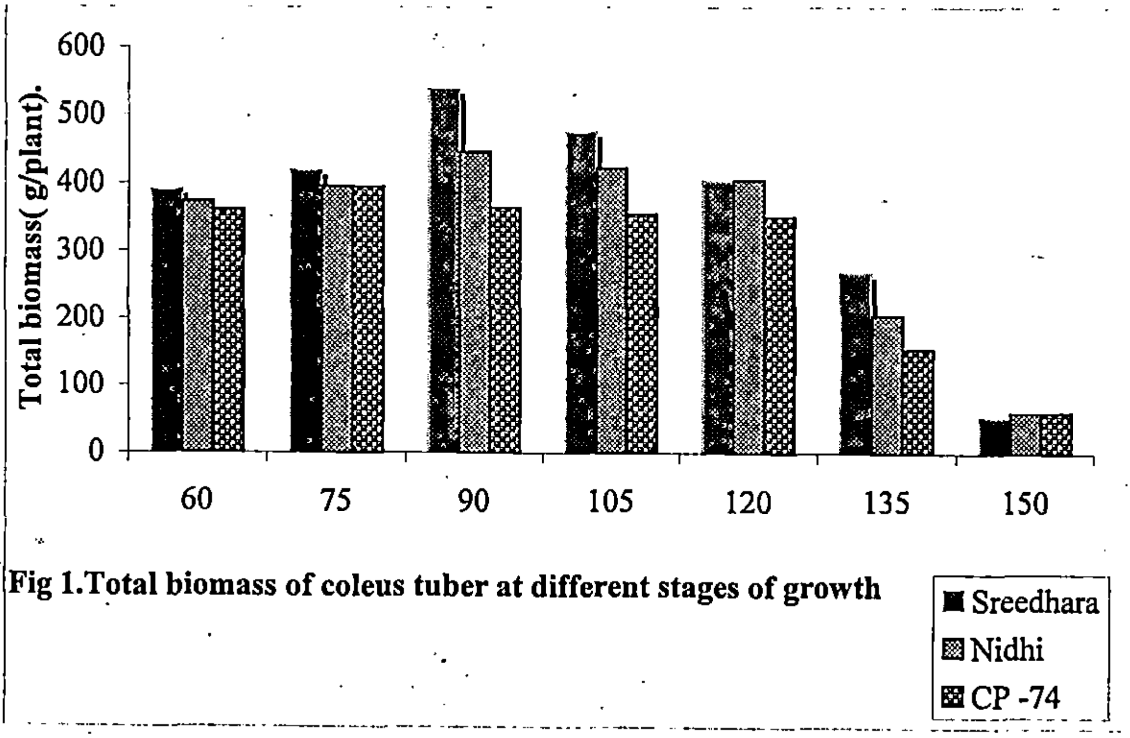

Fig 1.Total biomass of coleus tuber at different stages of growth

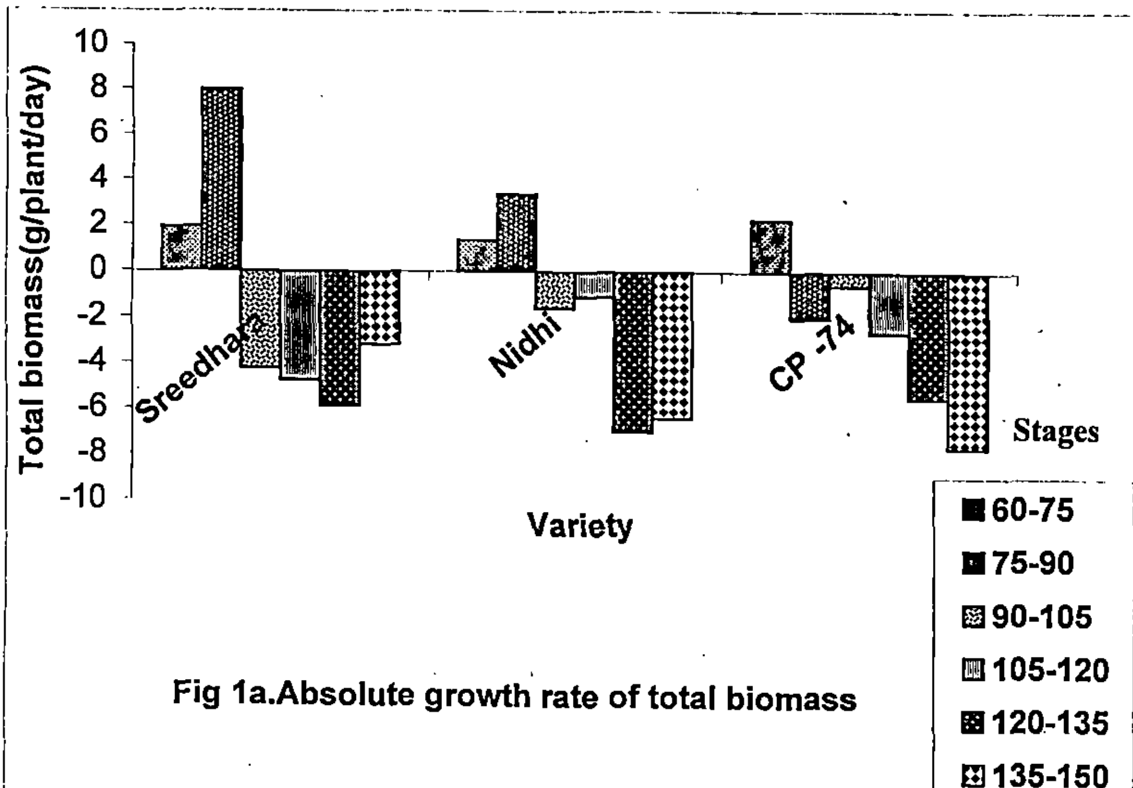

Fig 1a.Absolute growth rate of total biomass

Table 2. Biomass accumulation in leaf at different stages of growth

Variety	Mean leaf fresh weight (%)						
	Stage of Development (Days after transplanting)						
	60	75	90	105	120	135	150
Sreedhara	41.04	38.17	41.57	29.86	16.32	9.39 (2.86)*	-
Nidhi	42.48	41.72	41.95	30.87	20.19	2.65 (1.64)*	-
CP-74	49.98	41.66	45.69	29.28	24.00	6.05 (2.54)*	-
CD(0.05%)	6.46	NS	NS	NS	3.65	NS	

* Transformation for variable 7 by SQRT (V6 +0.5)

Table 2a. Pattern of dry matter accumulation in leaf at different stages of growth

Variety	Mean leaf dry weight (%)						
	Stage of Development (Days after transplanting)						
	60	75	90	105	120	135	150
Sreedhara	51.96	49.33	47.78	33.19	17.06	6.66	-
Nidhi	52.46	56.76	46.22	28.37	20.86	2.23	-
CP-74	52.96	49.96	47.25	25.85	22.44	4.99	-
CD(0.05%)	NS	3.39	NS	3.87	2.23	2.16	-

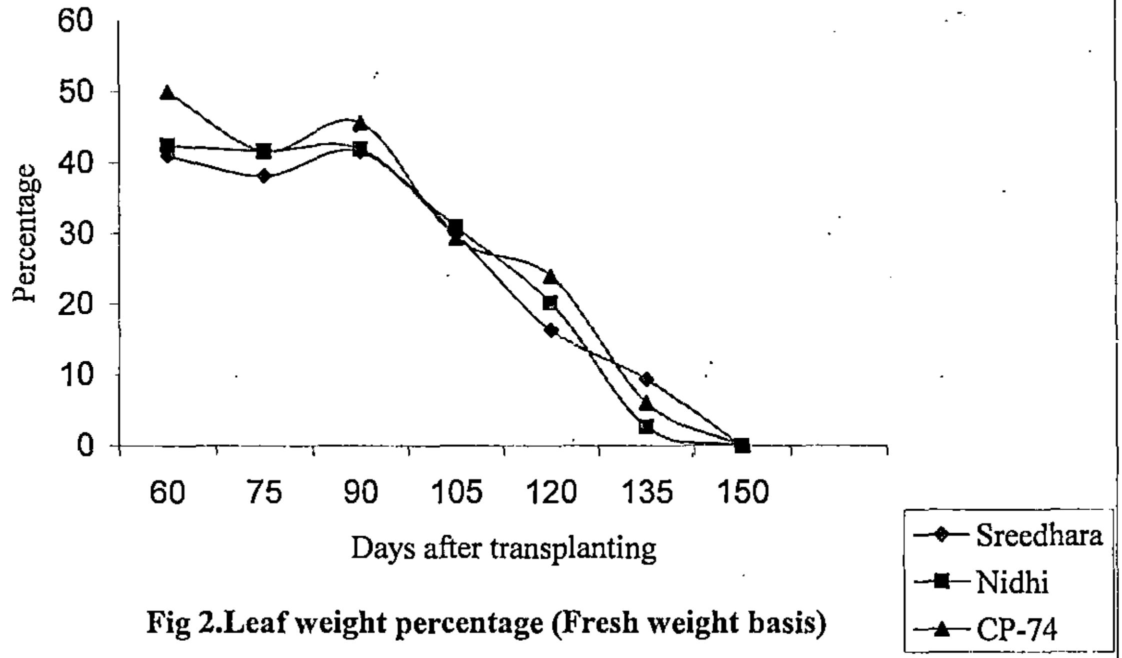

Fig 2.Leaf weight percentage (Fresh weight basis)

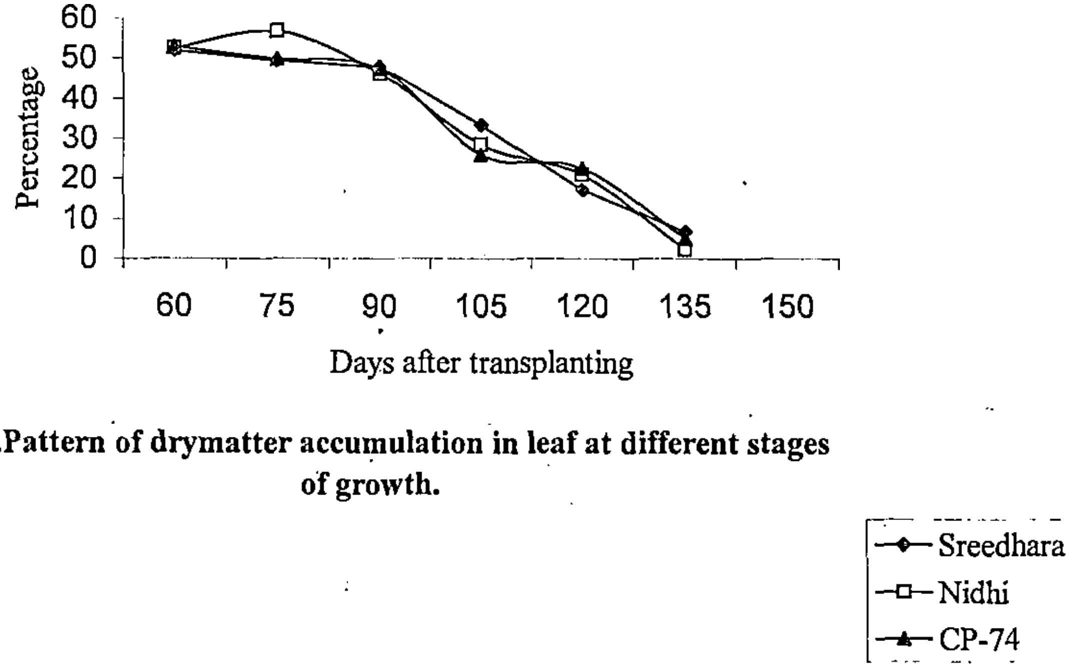

Fig 2a.Pattern of drymatter accumulation in leaf at different stages of growth.

The pattern of accumulation of dry matter in leaf during different stages of growth from 60 DAT is indicated in Table 2a and Fig 2a. At 60 DAT more than 50 per cent of total dry matter was in the leaves in all the varieties. There was a decline in the proportion of leaf biomass to total biomass up to harvest stage (150 DAT) when the leaf dry matter was negligible.

4.1.3 Fresh weight of Stem

The ratio of stem biomass in terms of fresh weight to the total biomass during different stages of growth from 60 DAT stage is indicated in Table 3 and Fig 3. At 60 DAT, it was 40.05 per cent in variety 'Sreedhara', 40.9 per cent in variety 'Nidhi' and 47.53 per cent in culture CP-74. At harvest stage, it was 16.66 per cent in variety 'Nidhi', 29.04 per cent in variety 'Sreedhara' and 20.97 per cent in CP-74. There was no significant difference between varieties.

The pattern of accumulation of dry matter in stem during different stages of growth from 60 DAT is indicated in Table 3a and Fig 3a. At 60 DAT, it ranged from 38.97 per cent in culture CP-74 to 39.94 per cent in variety 'Nidhi'. There was a gradual increase up to 105 DAT stage in all the varieties and from 105 DAT stage it declined.

4.1.4 Fresh weight of Root

The ratio of root biomass in terms of fresh weight to total biomass during different stages of growth is indicated in Table 4 and Fig 4. At 60 DAT, it ranged from 3.12 per cent in variety 'Nidhi' to 4.21 per cent in culture CP-74. The root fresh weight increased to 8.49 per cent in variety 'Sreedhara', 10.53 per cent in variety 'Nidhi' and 9.08 per cent in culture CP-74 by 120 DAT stage. There was a sharp decline in the proportion of root biomass after 120 DAT stage. Significant difference was observed between the varieties at all the stages of growth except 60 DAT stage.

Table 3. Biomass accumulation in stem at different stages of growth

Variety	Mean leaf fresh weight (%)						
	Stage of Development (Days after transplanting)						
	60	75	90	105	120	135	150
Sreedhara	40.05	46.28	57.19	62.15	67.4	56.57	29.04
Nidhi	40.90	45.76	54.71	66.95	65.64	51.29	16.66
CP-74	47.53	45.79	59.46	58.01	58.16	57.59	20.97
CD(0.05%)	NS	NS	NS	NS	NS	NS	NS

Table 3a. Pattern of dry matter accumulation in stem at different stages of growth

Variety	Mean stem dry weight (%)						
	Stage of Development (Days after transplanting)						
	60	75	90	105	120	135	150
Sreedhara	39.88	43.05	46.42	47.73	46.04	39.86	22.67
Nidhi	39.94	34.59	47.10	50.58	40.04	27.39	18.60
CP-74	38.97	40.71	45.26	51.98	38.27	34.08	17.03
CD(0.05%)	NS	3.29	NS	NS	NS	4.53	NS

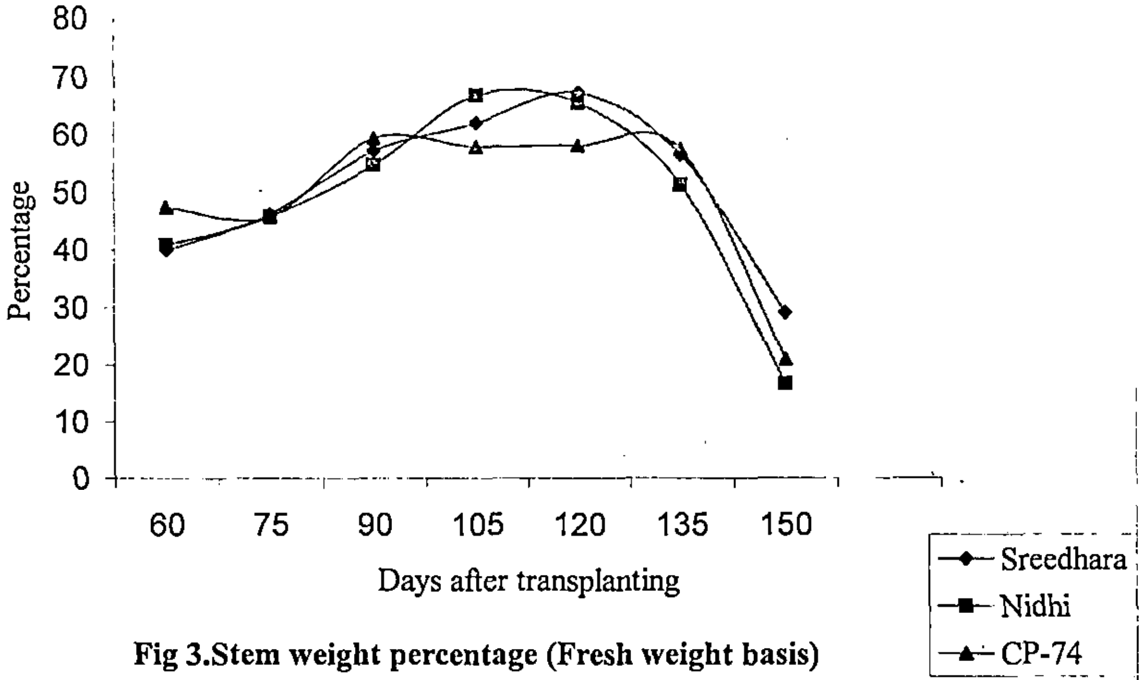

Fig 3.Stem weight percentage (Fresh weight basis)

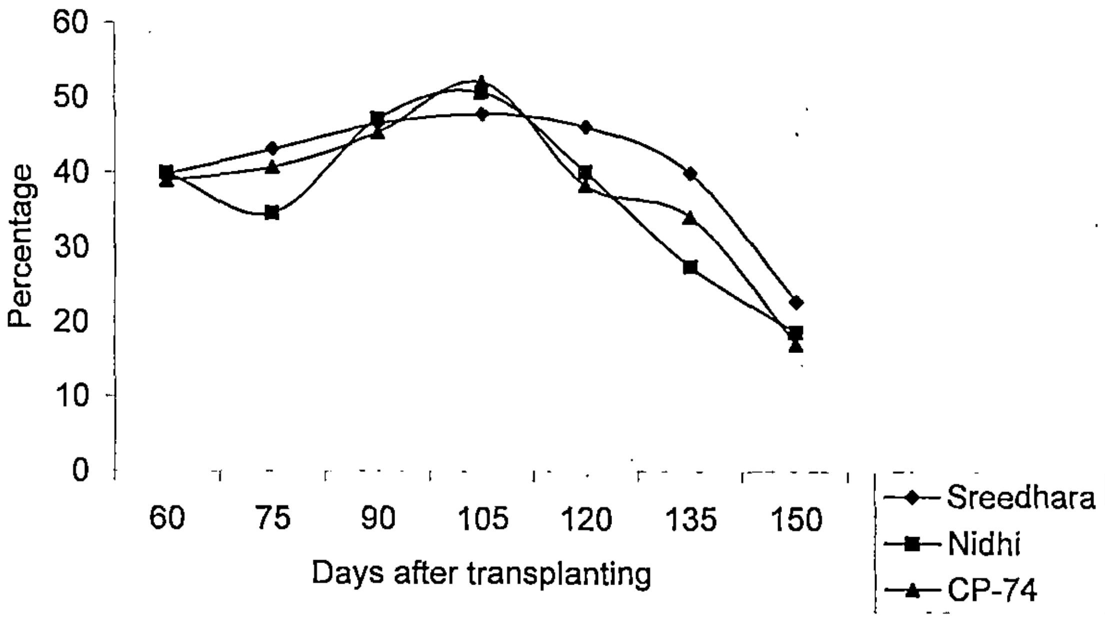

Fig 3a.Pattern of drymatter accumulation in stem at different stages of growth

Table 4. Biomass accumulation in root at different stages of growth

Variety	Mean root fresh weight (%)						
	Stage of Development (Days after transplanting)						
	60	75	90	105	120	135	150
Sreedhara	3.44	2.61	1.34	4.20	8.49	3.04	1.25
Nidhi	3.12	3.41	2.00	5.49	10.53	4.21	1.75
CP-74	4.21	2.74	2.01	5.46	9.08	6.81	2.68
CD(0.05%)	NS	0.65	0.48	0.46	1.68	1.64	NS

Table 4a. Pattern of dry matter accumulation in root at different stages of growth

Variety	Mean root dry weight (%)						
	Stage of Development (Days after transplanting)						
	60	75	90	105	120	135	150
Sreedhara	8.15	7.66	5.73	16.26	28.98	10.64	1.02
Nidhi	7.59	8.65	6.68	18.48	33.29	12.12	2.18
CP-74	8.06	9.33	7.49	18.93	30.55	23.18	2.50
CD(0.05%)	NS	NS	NS	1.88	1.25	1.23	NS

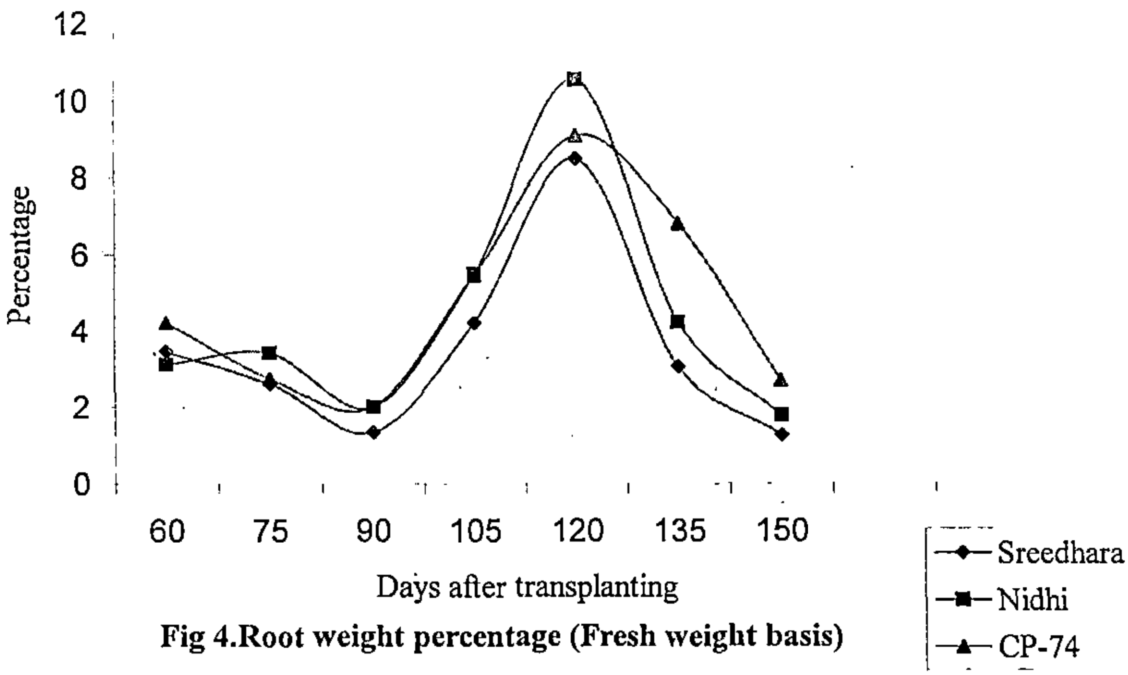

Fig 4.Root weight percentage (Fresh weight basis)

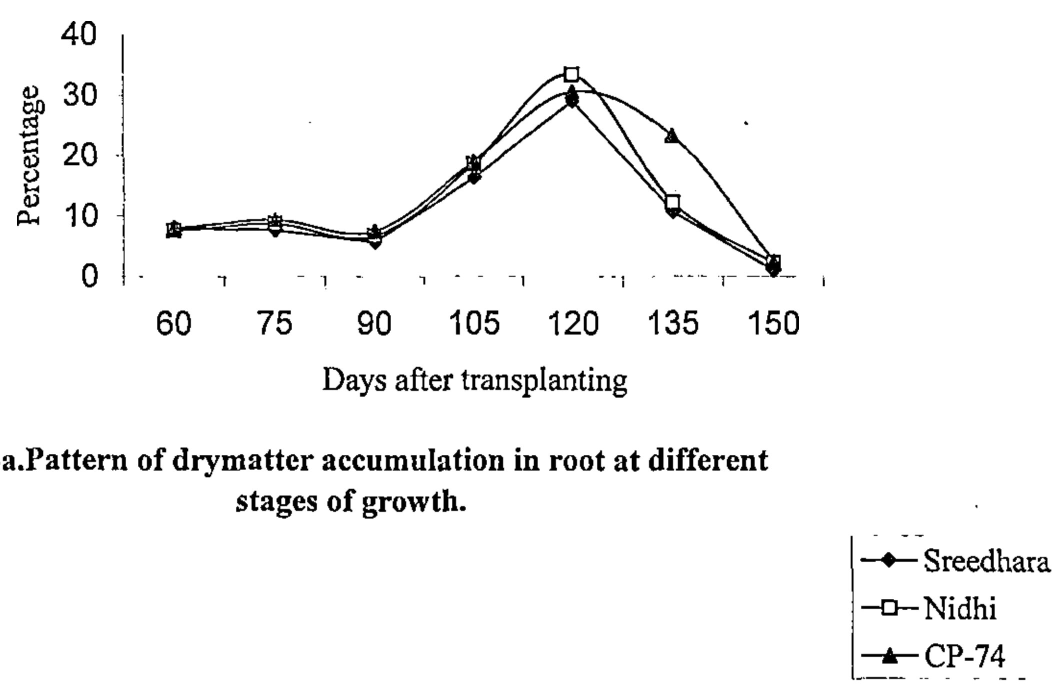

Fig 4a.Pattern of drymatter accumulation in root at different stages of growth.

The pattern of accumulation of dry matter in root during different stages of growth from 60 DAT is indicated in Table 4a and Fig 4a. At 60 DAT, it ranged from 7.59 per cent in variety 'Nidhi' to 8.15 per cent in variety 'Sreedhara'. There was a gradual increase up to 120 DAT stage in all the varieties.

4.1.5 Fresh weight of tuber

The ratio of tuber biomass in terms of fresh weight to total biomass during different stages of growth is indicated in Table 5 and Fig 5. The tuber initiation was observed after 90 DAT stage in all the varieties. At 90 DAT stage tubers formed 0.02 per cent of total fresh biomass in variety 'Sreedhara' and culture CP-74. The ratio increased up to 150 DAT stage in all the varieties. AT 150 DAT, it was 64.32 per cent in variety 'Sreedhara', 79.46 per cent in culture CP-74 and 81.49 per cent in variety 'Nidhi'. The difference between varieties was significant from 135 DAT stage onwards.

The pattern of accumulation of dry matter in tuber during different stages of growth from 90 DAT is shown in Table 5a and Fig 5a. At 90 DAT stage 0.07 per cent of total dry matter was partitioned to tubers in variety 'Sreedhara'. In culture CP-74 it was 0.008 per cent. An increasing trend was observed in all the varieties up to 150 DAT stage. At 150 DAT, it was 76.35 per cent in variety 'Sreedhara', 78.47 per cent in culture CP-74 and 79.22 per cent in variety 'Nidhi'.

The absolute growth rate of tuber showed a gradual increase up to the harvest stage (150 DAT) (Table 5b and Fig 5b). Growth rate was highest between 135 and 150 DAT stage in all the varieties. Among the varieties 'Nidhi' showed maximum growth rate of 1.98 g per plant per day between 135 and 150 DAT, followed by 'Sreedhara' with 1.34 g per plant per day during the same period.

4.1.6 Total number of tubers

Number of tubers at different stages of growth is shown in Table 6 and Fig 6. At tuber initiation stage (90 DAT) number of tubers varied from 0.07 per plant in culture CP-74 and 0.2 per plant in variety 'Sreedhara'. At 150 DAT, the variation was 8 to 11.17.

Table 5. Biomass accumulation in tubers at different stages of growth

Variety	Mean tuber fresh weight (%)						
	Stage of Development (Days after transplanting)						
	60	75	90	105	120	135	150
Sreedhara	-	-	0.02 (0.72)*	0.92	3.18	19.39	64.32
Nidhi	-	-	0.00 (0.7)*	0.88	2.52	32.27	81.49
CP-74	-	-	0.02 (0.72)*	1.19	3.71	19.28	79.46
CD(0.05%)	-	-	NS	NS	NS	9.15	14.09

*Transformation for variable 1 by SQRT (V_I+0.5)

Table 5a. Pattern of dry matter accumulation in tuber at different stages of growth

Variety	Mean tuber dry weight (%)						
	Stage of Development (Days after transplanting)						
	60	75	90	105	120	135	150
Sreedhara	-	-	0.07	2.43	8.04	42.84	76.35
Nidhi	-	-	0.00	6.59	5.81	56.01	79.22
CP-74	-	-	0.008	11.97	8.74	37.74	78.47
CD(0.05%)	-	-	NS	3.47	NS	4.32	NS

Table 5b. Absolute growth rate of economic biomass at different stages of growth

Variety	Absolute growth rate (g/plant/day)					
	Stages of development (Days after transplanting)					
	60-75	75-90	90-105	105-120	120-135	135-150
Sreedhara	-	-	0.29	0.56	1.13	1.34
Nidhi	-	-	0.25	0.43	1.62	1.98
CP-74	-	-	0.28	0.57	0.53	0.89

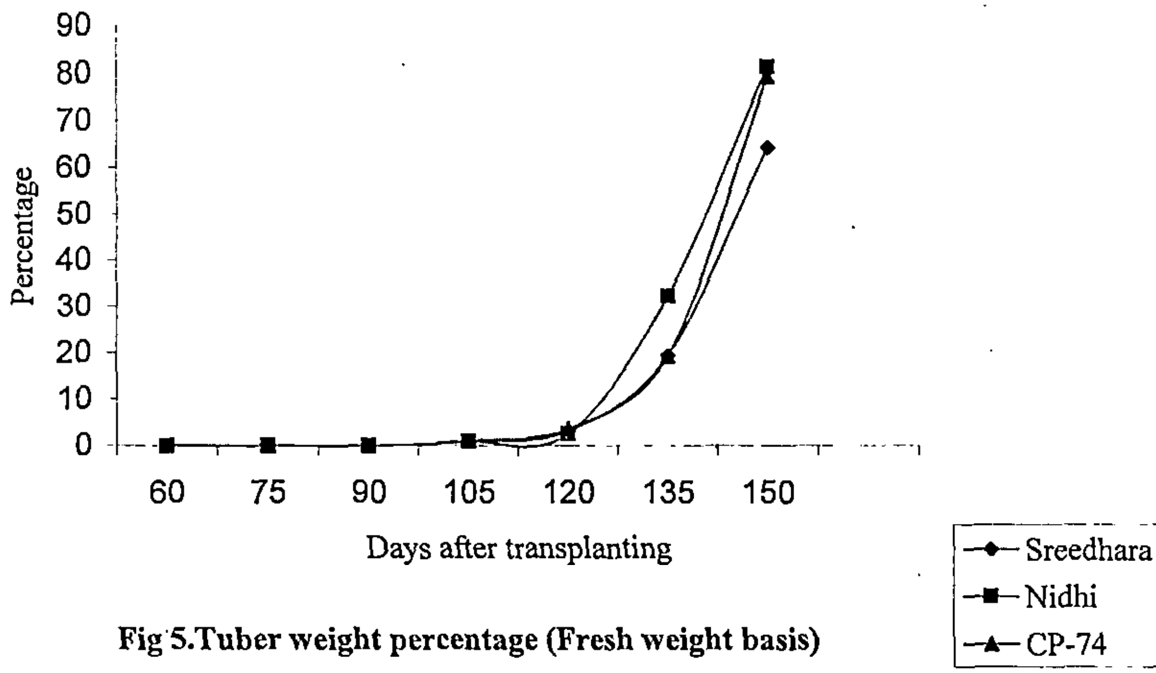

Fig 5.Tuber weight percentage (Fresh weight basis)

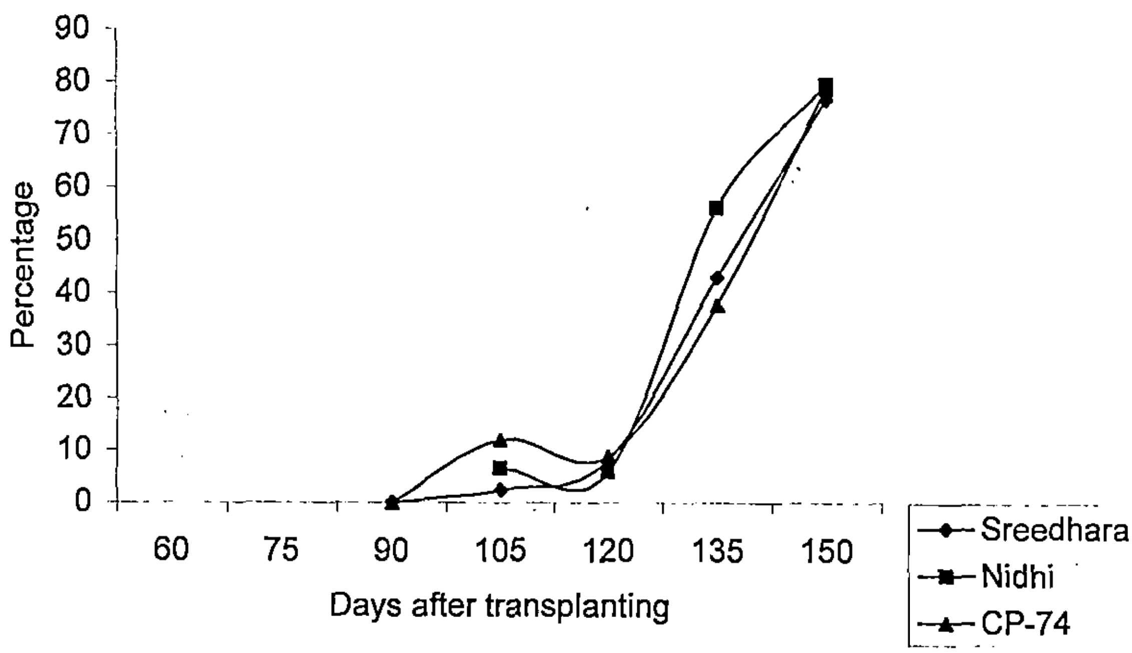

Fig 5a.Pattern of drymatter accumulation in tuber at different stages of growth

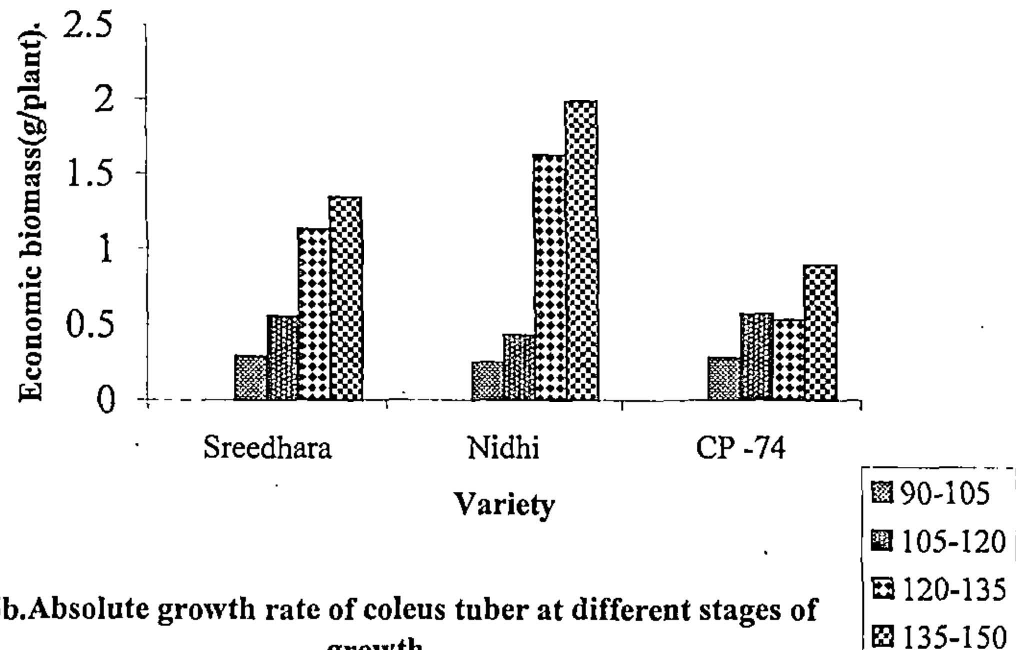

Fig 5b. Absolute growth rate of coleus tuber at different stages of growth

4.1.7 Length of tubers

Change in length of tubers at different stages of growth is presented in Table 7 and Fig 7. At 90 DAT, the average length was 0.58 cm in culture CP-74 and 0.75 cm in variety 'Sreedhara'. During the first 30 days after initiation there was a linear increase in length of tubers. The rate of increase of tuber length was lower beyond this stage. Maximum length was recorded at harvest stage, when it was 3.93 cm in Sreedhara, 4.36 cm in 'Nidhi' and 4.4 cm in Culture CP-74. Variation in length of tuber was significant at 135 DAT stage.

4.1.8 Diameter of tubers

Change in diameter of tubers at different stages of growth is shown in Table 8 and Fig 8. At 90 DAT, diameter was 0.03 cm in variety Sreedhara and culture CP-74. A gradual increase in diameter was observed in all the varieties. Maximum diameter was recorded at harvest stage (150 DAT) in variety 'Sreedhara' (2.24 cm) followed by 'Nidhi' (1.97 cm). There was no significant difference between other varieties.

4.1.9 Peel thickness

Change in peel thickness of tubers during different stages of growth is shown in Table 9. The mean thickness of peel at 90 DAT stages varied from 0.09 mm to 0.11 mm. There was an increase in peel thickness till harvest stage. At harvest stage thickness of the peel ranged from 0.29 mm in variety Nidhi and culture CP-74 to 0.3 mm in variety Sreedhara. Difference of peel thickness between varieties was not significant.

Percentage peel to the tuber weight during different stages of growth is given in Table 9a. At 105 DAT, the peel percentage varied from 8.17 in culture CP-74 to 8.83 in variety 'Nidhi'. At harvest stage, it varied from 9.83 per cent in variety 'Nidhi' and 11.33 per cent in variety 'Sreedhara'.

Table 6. Total number of tubers at different stages of growth

Variety	Mean number of tubers/plant						
	Stage of Development (Days after transplanting)						
	60	75	90	105	120	135	150
Sreedhara	-	-	0.20 (1.36)*	1.97	4.53	7.82	11.17
Nidhi	-	-	0.00 (1.71)*	1.47	3.65	6.9	10.98
CP-74	-	-	0.20 (1.36)*	1.63	3.52	5.27	8.00
CD(0.05%)	-	-	NS	NS	0.45	NS	1.9

*Transformation for variable 1 by SQRT (V_1+0.5)

Table 7. Length of coleus tubers at different stages of growth

Variety	Mean length (cm)						
	Stage of Development (Days after transplanting)						
	60	75	90	105	120	135	150
Sreedhara	-	-	0.75 (1.06)*	2.04	2.75	2.99	3.93
Nidhi	-	-	0.00 (0.7)*	1.85	2.72	3.59	4.36
CP-74	-	-	0.58 (0.99)*	2.05	2.93	3.48	4.40
CD(0.05%)	-	-	NS	NS	NS	0.31	NS

*Transformation for variable 1 by SQRT (V_1+0.5)

Table 8. Diameter of coleus tubers at different stages of growth

Variety	Mean diameter (cm)						
	Stage of Development (Days after transplanting)						
	60	75	90	105	120	135	150
Sreedhara	-	-	0.03 (1.1)*	0.86	1.32	1.69	2.24
Nidhi	-	-	0.00 (1.0)*	0.84	1.24	1.75	1.97
CP-74	-	-	0.03 (1.1)*	0.89	1.26	1.73	1.89
CD(0.05%)	-	-	NS	NS	NS	NS	NS

*Transformation for variable 1 by log (V_1+10)

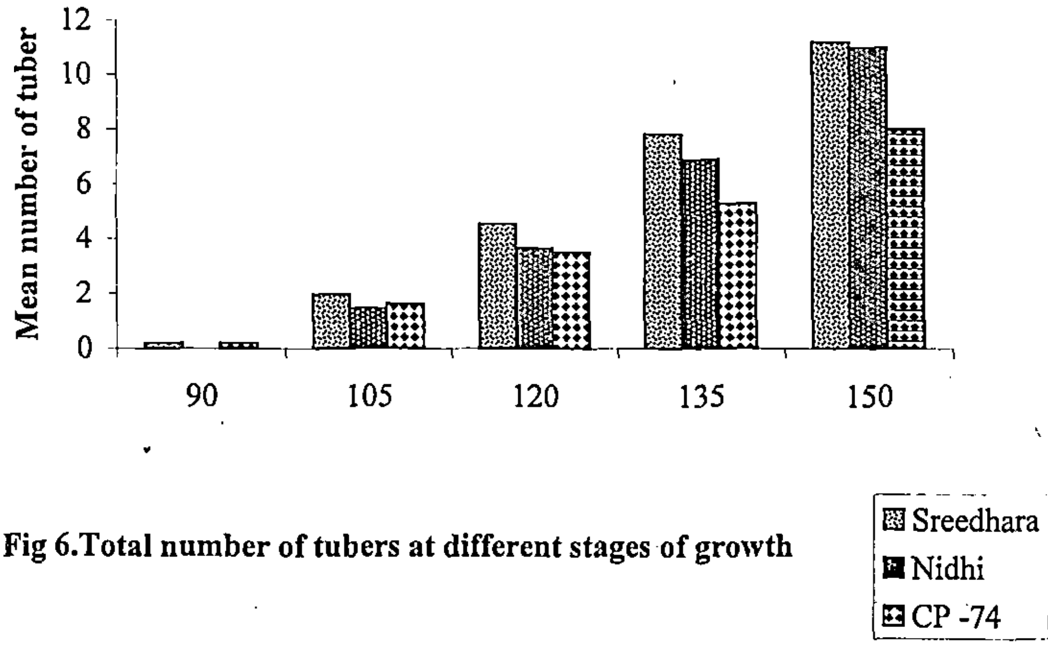

Fig 6.Total number of tubers at different stages of growth

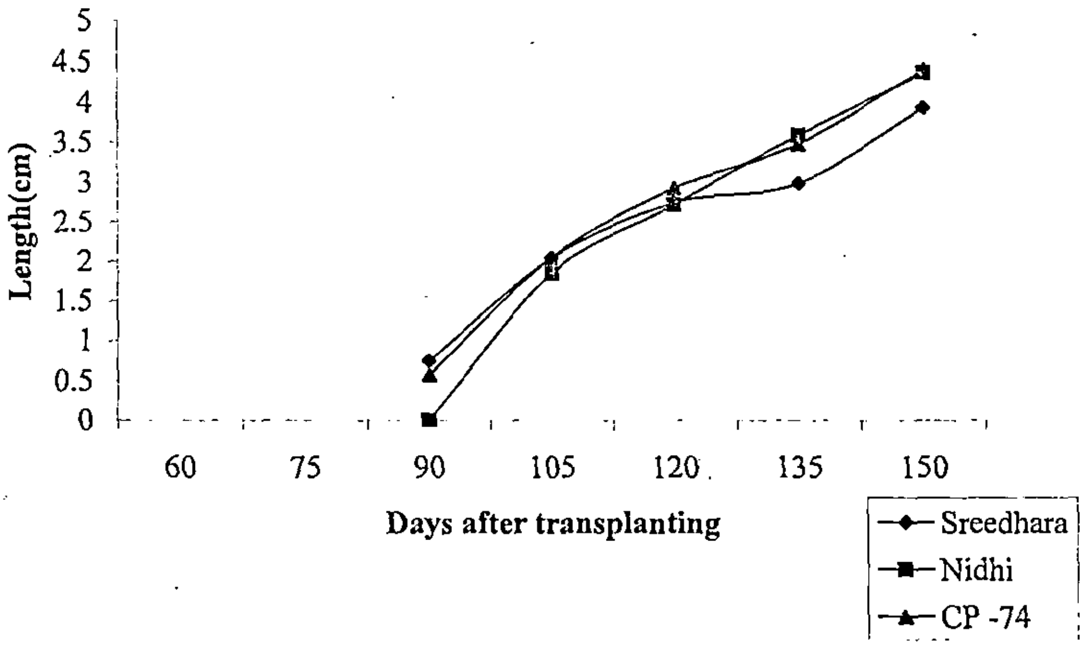

Fig 7.Length of coleus tuber at different stages of growth

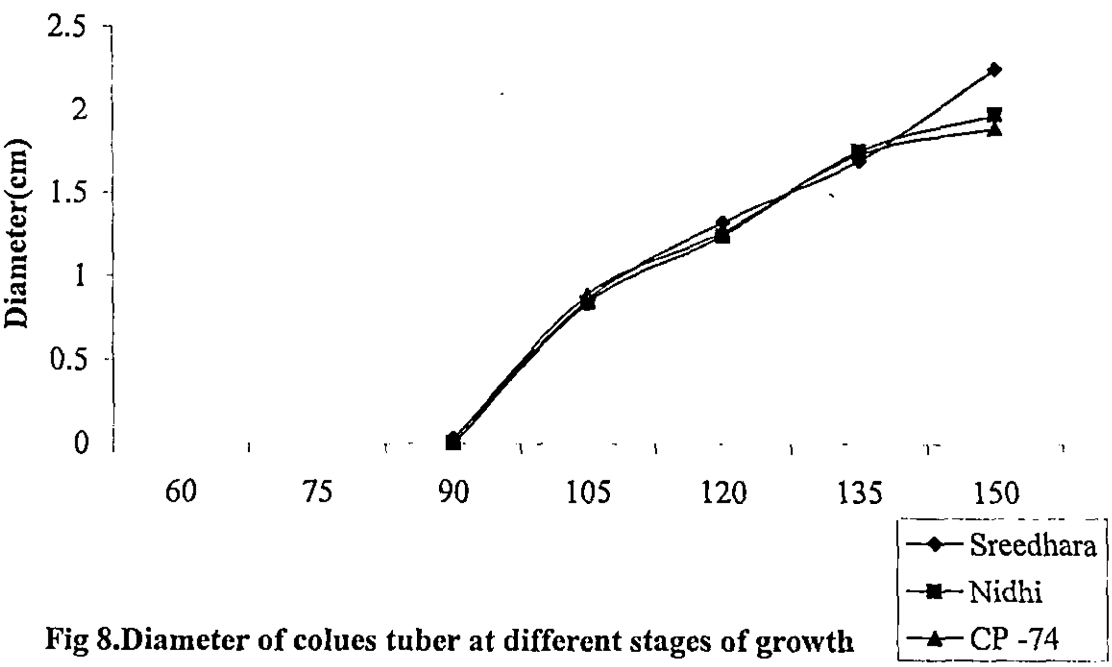

Fig 8.Diameter of colues tuber at different stages of growth

4.1.10 Specific gravity

Table 10 shows the change in specific gravity of coleus tubers at different stages of growth. At tuber initiation stage, (90 DAT) specific gravity ranged between 0.56 in variety Sreedhara and 0.64 in culture CP-74. By 105 DAT stage specific gravity increased to >1 in all types. At mature/harvest stage (150 DAT), it ranged from 1.15 in variety 'Nidhi' and culture CP-74 to 1.22 in variety 'Sreedhara'.

4.1.11 Colour changes in tuber

Change in colour of peel and flesh of coleus tuber during different stages of growth is shown in Table 11. The peel colour changed from yellowish brown (90 DAT stage) to brown (at 150 DAT stage). The flesh colour of tubers changed from yellowish cream during the initial stage (90 DAT) to cream at harvest stage (150 DAT).

4.1.12 Starch

Pattern of accumulation of starch in coleus tubers at different growth stages of tuber is shown in Table 12 and Fig 9. At the initiation stage (90 DAT) starch content varied from 5.73 per cent in variety 'Sreedhara' and 6.23 per cent in culture CP-74. There was a gradual increase in starch content up to the harvest stage when it ranged between 11.83 per cent in culture CP-74 to 13.57 per cent in variety 'Nidhi'. Difference between varieties was not significant.

4.1.13 Soluble sugars

Pattern of accumulation of sugar in coleus tuber during different stages of growth is shown in Table 13 and Fig 10. At 90 DAT, sugar content varied from 0.59 per cent in variety 'Sreedhara' and 0.62 per cent in culture CP-74. There was an increase in sugar content up to 135 DAT stage in all varieties, 0.68 per cent in variety 'Nidhi' and 0.88 per cent in variety 'Sreedhara'. There was a decline in sugar content beyond this stage. Variation among varieties was not significant except in 90 DAT and 135 DAT stage.

Table 9. Peel thickness of coleus tubers at different stages of growth

Variety	Mean peel thickness (mm)						
	Stage of Development (Days after transplanting)						
	60	75	90	105	120	135	150
Sreedhara	-	-	0.09 (0.77)*	0.19	0.20	0.19	0.30
Nidhi	-	-	0.00 (0.7)*	0.20	0.20	0.21	0.29
CP-74	-	-	0.11 (0.77)*	0.24	0.20	0.21	0.29
CD(0.05%)	-	-	NS	NS	NS	NS	NS

*Transformation for variable 1 by log (V_1+10)

Table 9a. Peel percentage of coleus tubers at different stages of growth

Variety	Peel percentage						
	Stage of Development (Days after transplanting)						
	60	75	90	105	120	135	150
Sreedhara	-	-	-	8.33	8.83	10.67	11.33
Nidhi	-	-	-	8.83	10.17	9.83	9.83
CP-74	-	-	-	8.17	9.33	10.33	11.00
CD(0.05%)	-	-	-	NS	NS	NS	NS

Table 10.Specific gravity of coleus tubers at different stages of growth

Variety	Specific gravity						
	Stage of Development (Days after transplanting)						
	60	75	90	105	120	135	150
Sreedhara	-	-	0.56 (0.99)*	1.18	1.28	1.30	1.22
Nidhi	-	-	0.00 (0.7)*	1.34	1.35	1.29	1.15
CP-74	-	-	0.64 (1.02)*	1.31	1.39	1.34	1.15
CD(0.05%)	-	-	NS	NS	NS	NS	NS

*Transformation for variable 1 by SQRT (V_1+0.5)

Table 11.Change of tuber colour at different stages of growth

Variety		Stages of development (Days after transplanting)						
		60	75	90	105	120	135	150
Sreedhara	Peel	-	-	Yellowish brown	Light brown	Light brown	Brown	Brown
	Flesh	-	-	Yellowish cream	Light cream	Light cream	Cream	Cream
Nidhi	Peel	-	-	-	Light brown	Light brown	Brown	Brown
	Flesh	-	-	-	Light cream	Light cream	Cream	Cream
CP-74	Peel	-	-	Yellowish brown	Light brown	Light brown	Brown	Brown
	Flesh	-	-	Yellowish cream	Light cream	Light cream	Cream	Cream

Table 12. Starch content of coleus tubers at different stages of growth

Variety	Starch content (%)						
	Stage of Development (Days after transplanting)						
	60	75	90	105	120	135	150
Sreedhara	-	-	5.73	7.75	9.81	11.75	13.55
Nidhi	-	-	-	7.88	9.51	11.05	13.57
CP-74	-	-	6.23	7.12	10.7	10.83	11.83
CD(0.05%)	-	-	NS	NS	NS	NS	NS

Table 13. Sugar content of coleus tubers at different stages of growth

Variety	Sugar content (%)						
	Stage of Development (Days after transplanting)						
	60	75	90	105	120	135	150
Sreedhara	-	-	0.59	0.75	0.76	0.88	0.54
Nidhi	-	-	-	0.65	0.77	0.68	0.61
CP-74	-	-	0.62	0.69	0.69	0.83	0.59
CD(0.05%)	-	-	0.15	NS	NS	0.15	NS

Table 14. Polyphenol content of coleus tubers at different stages of growth

Variety	Polyphenol content (%)						
	Stage of Development (Days after transplanting)						
	60	75	90	105	120	135	150
Sreedhara	-	-	0.09	0.11	0.12	0.21	0.23
Nidhi	-	-	-	0.06	0.07	0.15	0.20
CP-74	-	-	0.08	0.09	0.10	0.22	0.24
CD(0.05%)	-	-	0.02	0.02	0.01	0.01	0.02

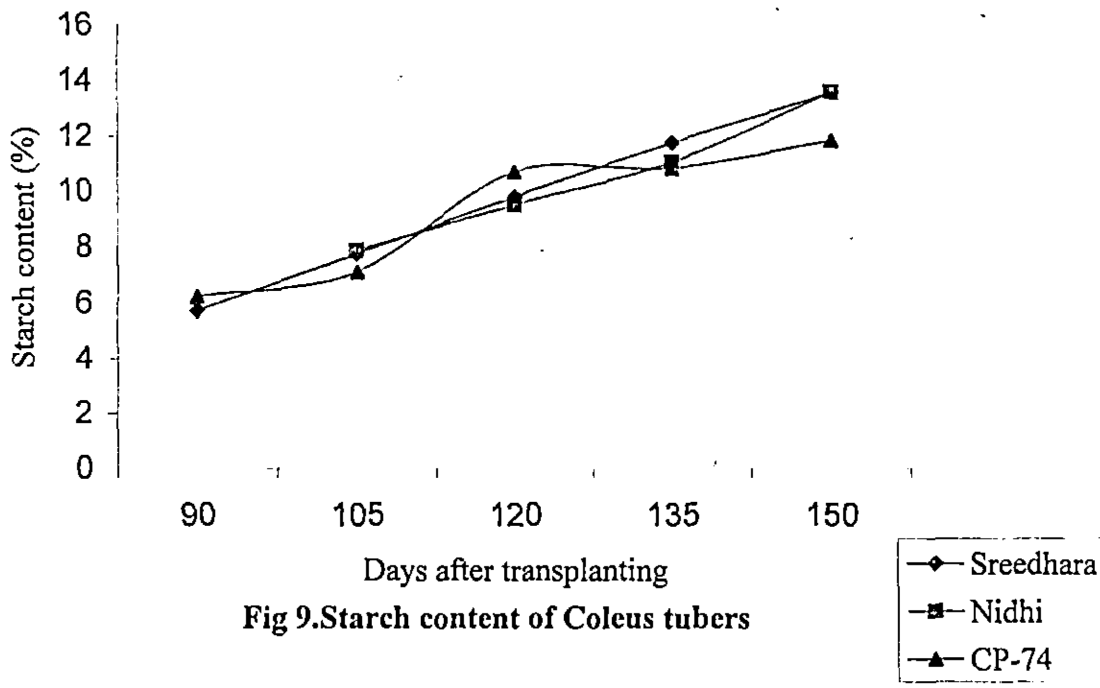

Fig 9.Starch content of Coleus tubers

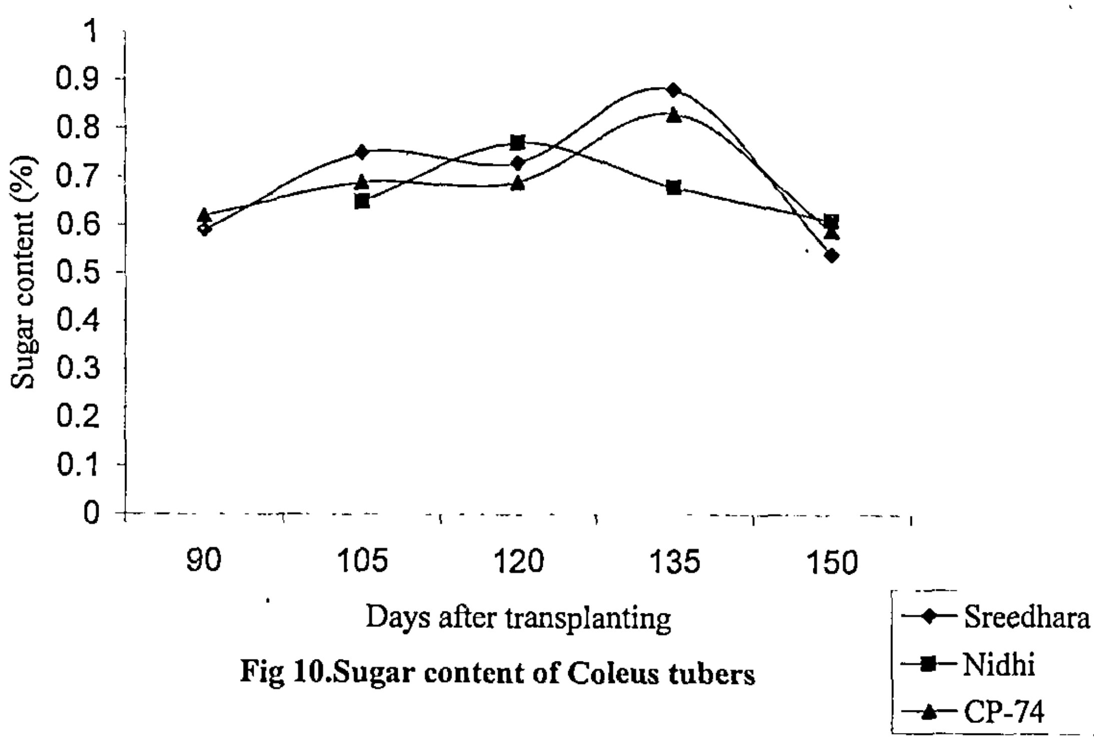

Fig 10.Sugar content of Coleus tubers

4.1.14 Polyphenols

Pattern of accumulation phenolic substances in coleus tuber during different stage of tuber growth is shown in Table 14 and Fig11. At the initiation stage (90 DAT) polyphenol content varied from 0.08 per cent in culture CP-74 and 0.09 per cent in variety 'Sreedhara'. Polyphenol content increased up to the harvest stage, ranged up to 0.20 per cent in variety 'Nidhi' and 0.24 in culture CP-74. There was significant difference between varieties.

4.1.15 Quality parameters of nematode infested tubers

Comparison of quality parameters (starch, sugar, polyphenol) of nematode infested tubers and non-infested tuber at harvest stage is shown in Table 15. Starch content of nematode infested tuber was found to be low when compared to non-infested ones. In the infested tubers, it ranged from 6.69 per cent in culture CP-74 and 11.17 per cent in variety 'Sreedhara' while in non-infested tubers it ranged from 11.83 per cent in culture CP-74 and 13.57 per cent in variety 'Nidhi'. Sugars and polyphenols were higher in infested tubers compared to non-infested one. Sugar content in infested tubers ranged from 0.66 per cent in variety 'Nidhi' to 0.84 per cent in variety 'Sreedhara' and in non-infested tubers, it varied from 0.54 per cent in variety 'Sreedhara' and 0.61 per cent in variety 'Nidhi'. Polyphenol content ranged from 0.28 per cent to 0.34 per cent in infested tubers while in non-infested tubers it varied from 0.2 to 0.24 per cent.

4.1.16 Sensory quality

Sensory qualities of coleus tubers harvested at different intervals were assessed through a scoring technique and was analysed by Kruskal-Wallis one-way Anova.

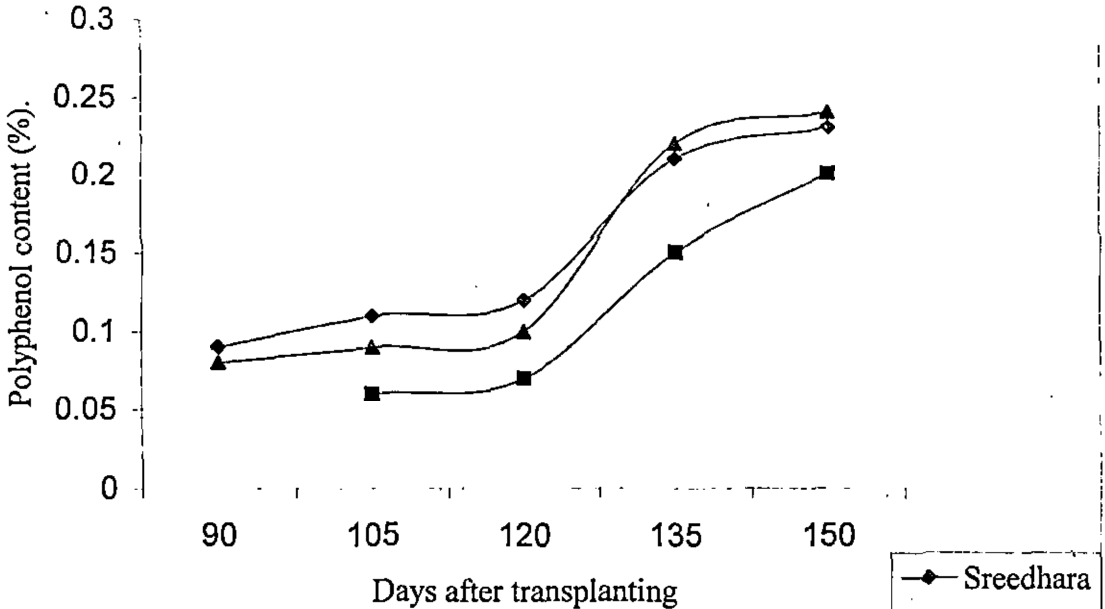

Fig 11.Polyphenol content of Coleus tubers

Table 15. Quality parameters of nematode infested tubers

Variety	Starch (% in fwb)		Sugar (% in fwb)		Polyphenol (% in fwb)	
	Infested	Non-infested	Infested	Non-infested	Infested	Non-infested
Sreedhara	11.17	13.55	0.84	0.54	0.34	0.23
Nidhi	8.39	13.57	0.66	0.61	0.30	0.20
CP-74	6.69	11.83	0.69	0.59	0.28	0.24

4.1.16.1 Colour

Scoring based on colour of the coleus tubers at different harvest intervals is shown in Table 16. At the mature stage variety 'Sreedhara' obtained highest score (6.83) followed by 'Nidhi' and culture CP-74 (6).

4.1.16.2 Appearance

Table 16a shows the appearance of harvested tubers at different intervals. Significant difference was observed between the varieties at 105 and 120 DAT stages. At the harvest stage variety 'Nidhi' showed good appearance (6.5) followed by culture CP-74 (6.32).

4.1.16.3 Texture

Texture of coleus tuber at different harvest intervals is shown in Table 16b. A significant difference in texture was observed at harvest stage. At this stage the maximum score was 7.33 (CP-74) and minimum 6.0 for 'Nidhi'.

4.1.16.4 Aroma

Table 16c shows aroma of coleus tubers harvested at different intervals. It was observed that there is significant difference at 105, 135 and 150 DAT stages. At harvest stage, culture CP-74 recorded maximum score for aroma (6.67) followed by variety 'Sreedhara' with a score of six.

4.1.16.5 Taste

Taste of tubers at different intervals is given in Table 16d. It was observed that there was no significant difference between the varieties at different stages except at the harvest stage. At this stage, a good taste was noticed in culture CP-74 (6.17) followed by variety 'Sreedhara' (6).

4.1.16.6 Overall acceptability

The over all acceptability of tubers harvested at different intervals is shown in Table 16e. A significant difference was observed in 120 and 150 DAT stages.

Table 16. Evaluation of coleus tuber harvested at different intervals based on colour

Variety	Days after transplanting				
	90	105	120	135	150
Sreedhara	-	5.00	5.50	5.83	6.83
Nidhi	-	5.17	6.50	7.17	6.00
CP-74	-	6.33	5.67	6.67	6.00
Kruskal Wallis H (5%)	-	4.90	1.86	0.67	2.09

Table 16a. Evaluation of coleus tuber harvested at different intervals based on appearance

Variety	Days after transplanting				
	90	105	120	135	150
Sreedhara	-	4.67	5.17	5.67	6.00
Nidhi	-	5.00	5.67	5.67	6.50
CP-74	-	6.00	6.00	6.33	6.32
Kruskal Wallis H (5%)	-	7.12*	14.18*	2.36	2.69

*Values differed significantly at 5% level

Table 16b. Evaluation of coleus tuber harvested at different intervals based on texture

Variety	Days after transplanting				
	90	105	120	135	150
Sreedhara	-	5.00	5.00	6.17	6.83
Nidhi	-	5.07	5.67	5.00	6.00
CP-74	-	6.67	5.50	6.33	7.33
Kruskal Wallis H (5%)	-	5.08	2.98	4.72	10.45*

*Values differed significantly at 5% level

Table 16c. Evaluation of coleus tuber harvested at different intervals based on aroma

Variety	Days after transplanting				
	90	105	120	135	150
Sreedhara	-	5.00	5.00	5.83	6.00
Nidhi	-	5.67	5.33	6.67	5.00
CP-74	-	6.00	5.17	5.5	6.67
Kruskal Wallis H (5%)	-	8.67*	0.64	7.29*	12.87*

* Values differed significantly at 5% level

Table 16d. Evaluation of coleus tuber harvested at different intervals based on taste

Variety	Days after transplanting				
	90	105	120	135	150
Sreedhara	-	5.00	5.00	4.67	6.00
Nidhi	-	4.33	4.50	5.67	4.83
CP-74	-	5.00	5.00	5.50	6.17
Kruskal Wallis H (5%)	-	4.10	2.25	3.65	9.84*

*Values differed significantly at 5% level

Table 16e. Evaluation of coleus tuber harvested at different intervals based on overall acceptability

Variety	Days after transplanting				
	90	105	120	135	150
Sreedhara	-	4.83	4.83	5.83	6.83
Nidhi	-	4.83	6.00	5.50	6.85
CP-74	-	5.83	6.50	6.00	5.13
Kruskal Wallis H (5%)	-	4.97	8.34*	1.84	11.19*

* Values differed significantly at 5% level

At 150 DAT stage acceptability was more for 'Nidhi' (6.85) followed by 'Sreedhara' (6.83).

4.2 STORAGE OF COLEUS TUBER

Coleus Tuber (Variety 'Nidhi') was kept under different storage conditions and the change in quantitative and qualitative parameters were studied. Spoilage of a maximum of 20 per cent of the tubers was considered as the benchmark, beyond which the material was considered unmarketable.

4.2.1 Sprouting

Sprouting of tubers under different storage conditions is shown in Table 17. Sprouting started 30 days after storage (DAS) in all the storage conditions except in low temperature storage. Under room temperature storage 6.15 per cent to 17.37 per cent of sprouting was observed at 45 DAS up to which tubers retained marketability. Tubers stored under zero energy cool chamber condition showed marketability up to 60 DAS, at this stage the sprouting ranged between 4.45 per cent to 8.05 per cent. Under low temperature storage conditions (8-10°C and frozen) the spoilage started after 15 DAS stage and no sprouting occurred. Tubers stored in pits showed 10.85 per cent of sprouting at 45 DAS, beyond which it lost marketability.

4.2.2 Spoilage due to micro-organisms

Spoilage of stored tubers under different conditions is shown in Table 18. Under room temperature, spoilage was noticed from 30 DAS in packed conditions, which ranged from 0.75 per cent to one per cent where as no spoilage occurred in tubers under open condition at this stage. The spoilage under zero energy cool chamber at 60 DAS, ranged from 2.25 per cent to 3.25 per cent up to which it retained marketability. Under low temperature conditions of 8-10°C and in deep freezer, the spoilage was high when compared to ambient conditions. Under 8-10°C, the spoilage of tubers ranged from 21 per cent to 52.5 per cent at

Table 17. Sprouting of coleus tuber under different storage conditions and methods

Condition of storage	Method of storage	Mean value of sprouting (%)				
		Days after storage				
		0	15	30	45	60*
Room temperature	Open	-	-	8.35	17.37	-
	Gunny bag	-	-	4.70	9.35	-
	Polythene lined gunny bag	-	-	3.50	6.15	-
Zero energy cool chamber	Open	-	-	2.50	4.50	8.05
	Gunny bag	-	-	2.75	3.40	6.65
	Polythene lined gunny bag	-	-	2.95	3.00	4.45
8-10°C	Open	-	-	Spoiled	Spoiled	Spoiled
	Gunny bag	-	-	”	”	”
	Polythene lined gunny bag	-	-	”	”	”
Deep freezer	Open	-	-	”	”	”
	Gunny bag	-	-	”	”	”
	Polythene lined gunny bag	-	-	”	”	”
Room temperature		-	-	5.52	10.96	-
Zero energy cool chamber		-	-	2.57	3.63	-
8-10°C		-	-	-	-	-
Deep freezer		-	-	-	-	-
	Open			5.43	10.94	-
	Gunny bag			3.48	6.38	-
	Polythene lined gunny bag			3.23	4.58	-
	Pit	-	-	6.95	10.85	-
CD for condition of storage		-	-	0.39	3.12	-
CD for method of storage		-	-	0.34	2.18	-
CD for methods within condition		-	-	0.64	5.40	-

* Values are not analysed statistically

Table 18. Spoilage of coleus tuber under different storage conditions and methods

Condition of storage	Method of storage	Mean spoilage value (%)				
		Days after storage				
		0	15	30	45*	60*
Room temperature	Open	-	-	-	1.00	-
	Gunny bag	-	-	1.00	1.00	-
	Polythene lined gunny bag	-	-	0.75	0.75	-
Zero energy cool chamber	Open	-	-	3.00	3.00	3.25
	Gunny bag	-	-	2.25	2.25	2.25
	Polythene lined gunny bag	-	-	2.75	2.75	3.00
8-10°C	Open	-	-	52.50	-	-
	Gunny bag	-	-	35.00	-	-
	Polythene lined gunny bag	-	-	21.00	-	-
Deep freezer	Open	-	-	50.00	-	-
	Gunny bag	-	-	55.00	-	-
	Polythene lined gunny bag	-	-	60.00	-	-
Room temperature		-	-	0.33	0.92	-
Zero energy cool chamber		-	-	1.28	2.67	2.83
8-10°C		-	-	12.33	-	-
Deep freezer		-	-	22.83	-	-
	Open	-	-	11.69	-	-
	Gunny bag	-	-	9.28	-	-
	Polythene lined gunny bag	-	-	6.63	-	-
	Pit	-	-	2.30	2.30	-
CD for condition of storage		-	-	1.91	-	-
CD for method of storage		-	-	1.66	-	-
CD for methods within condition		-	-	3.31	-	-

* Values are not analysed statistically

30 DAS stage. Tubers kept under frozen condition showed 50-60 per cent spoilage at 30 DAS stage. It indicated that tubers under low temperature could be stored up to 15 DAS stage beyond which it lost its marketability. Tuber stored in pits showed 2.3 per cent of spoilage at 30 DAS stage. At 45 DAS stage 2.30 per cent of spoilage was observed. Among the different storage conditions, minimum spoilage was observed in room temperature storage followed by zero energy cool chamber and storage in pits.

4.2.3 Physiological loss in weight (PLW)

Changes in PLW recorded at 15 day intervals in all the storage conditions of tubers are presented in Table 19. Tubers stored under room temperature conditions retained marketability up to 45 DAS. At this stage the PLW ranged from 11.5 per cent to 16.75 per cent. It was observed that PLW increased with storage, 7.5 per cent (15 DAS) to 16.75 per cent (45 DAS) PLW was recorded under different methods of storage. Tubers stored under zero energy cool chamber remained marketability up to 60 DAS stage and the PLW varied from 4.75 per cent to 10.75 per cent at this stage. Under low temperature storage (8-10°C) and frozen storage, the PLW varied from 1.25 per cent to 2.5 per cent at 15 DAS stage. The tubers lost marketability due to spoilage afterwards. Tubers stored in pits showed PLW of 5.25 per cent at 45 DAS stage, tubers retained marketability at this stage. Storage in pit was better in terms of storage life and had low PLW compared to storage under room temperature condition.

4.2.4 Starch content

Table 20 shows the changes in starch content in tubers under different storage conditions. The starch content declined during storage. Storage under room temperature recorded 18.46 per cent reduction at 45 DAS stage. In zero energy cool chamber at 60 DAS there was 9.66 per cent reduction, while 8.98-12.67 percent reduction was recorded when stored under low temperature conditions (8-10°c and frozen) at 15 DAS. Tubers stored in pit showed 18.12 per cent reduction in starch content at 45 DAS stage.

Table 19. Physiological loss in weight of coleus tuber under different storage conditions and methods

Condition of storage	Method of storage	PLW (%)				
		Days after storage				
		0	15	30*	45*	60*
Room temperature	Open	-	13.00	16.00	16.75	-
	Gunny bag	-	9.00	11.50	14.75	-
	Polythene lined gunny bag	-	7.50	10.00	11.50	-
Zero energy cool chamber	Open	-	5.75	7.25	9.00	10.75
	Gunny bag	-	3.75	4.35	4.65	4.75
	Polythene lined gunny bag	-	3.05	3.65	4.10	4.75
8-10°C	Open	-	2.25	-	-	-
	Gunny bag	-	1.25	-	-	-
	Polythene lined gunny bag	-	1.25	-	-	-
Deep freezer	Open	-	2.50	-	-	-
	Gunny bag	-	1.58	-	-	-
	Polythene lined gunny bag	-	2.40	-	-	-
Room temperature		-	9.83	12.50	14.33	-
Zero energy cool chamber		-	4.18	5.08	5.92	6.75
8-10°C		-	2.25	-	-	-
Deep freezer		-	2.37	-	-	-
	Open	-	9.83	11.63	12.88	-
	Gunny bag	-	4.18	7.93	9.70	-
	Polythene lined gunny bag	-	2.25	6.83	7.80	-
	Pit	-	2.25	4.50	5.25	-
CD for condition of storage		-	1.32	-	-	-
CD for method of storage		-	1.14	-	-	-
CD for methods within condition		-	2.29	-	-	-

* Values are not analysed statistically

Table 20. Starch content of coleus tuber under different storage conditions and methods

Condition of storage	Method of storage	Starch content (%)				
		Days after storage				
		0	15	30*	45*	60*
Room temperature	Open	67.5	66.53(1.44)	59.25(12.22)	55.92(17.15)	-
	Gunny bag	72.75	69.78(4.08)	61.86(14.96)	57.00(21.65)	-
	Polythene lined gunny bag	70.86	68.51(3.32)	61.50(13.14)	59.251(6.38)	-
Zero energy cool chamber	Open	70.50	69.75(1.06)	67.68(4.00)	66.83(5.21)	63.75(9.57)
	Gunny bag	72.00	70.08(2.66)	68.86(4.36)	68.25(5.21)	65.43(9.13)
	Polythene lined gunny bag	71.25	68.89(3.31)	66.86(6.16)	66.59(6.54)	63.89(10.33)
8-10°C	Open	70.23	63.75(9.23)	-	-	-
	Gunny bag	71.25	59.25(16.84)	-	-	-
	Polythene lined gunny bag	72.38	63.0012.95)	-	-	-
Deep freezer	Open	70.50	64.29(8.81)	-	-	-
	Gunny bag	72.00	63.36(12.00)	-	-	-
	Polythene lined gunny bag	69.44	65.25(6.03)	-	-	-
Room temperature		70.38	68.26(3.07)	60.87(13.51)	57.39(18.46)	-
Zero energy cool chamber		71.25	69.57(2.36)	67.80(4.84)	67.22(5.65)	64.36(9.66)
8-10°C		70.98	61.99(12.67)	-	-	-
Deep freezer		70.64	64.29(8.98)	-	-	-
	Open	69.69	66.07(5.19)	63.46(8.94)	61.37(11.94)	-
	Gunny bag	72.00	65.63(8.84)	65.36(9.22)	62.63(13.01)	-
	Polythene lined gunny bag	71.07	66.42(6.54)	64.18(9.69)	62.92(11.47)	-
	Pit	69.00	65.28(5.39)	59.69(13.51)	56.5(18.12)	-
CD for condition of storage		1.76	2.19	-	-	-
CD for method of storage		2.15	1.89	-	-	-
CD for methods within condition		2.53	2.82	-	-	-

* Values are not analysed statistically. Values in parentheses indicate percentage reduction of starch content

4.2.5 Sugar content

Changes in sugar content in tubers under different storage conditions are shown in Table 21. The sugar content increased under all conditions of storage. Under room temperature condition tuber was marketable up to 45 DAS stage and by this time there was 31.46 per cent increase in soluble sugar content. Tubers stored under zero energy cool chamber showed 27.91 per cent of increase in sugar content at 60 DAS stage. Under low temperature conditions, (8-10°C and Frozen) the soluble sugar content increased 33.33-45.78 per cent at 15 DAS. Tubers stored under pit showed 31.18 per cent increase of soluble sugar content at 45 DAS stage up to which it retained it's marketability.

4.2.6 Polyphenols

Fresh tubers had polyphenols ranging between 0.17 to 0.21 per cent. Definite pattern was not indicated in the polyphenol content after storage. Under room temperature condition when marketability was up to 45 days, the polyphenol content recorded was between 0.17 and 0.19 per cent (Table 22). It ranged between 0.13 to 0.14 percent after 60 days in zero energy cool chamber. No definite pattern could be seen under low temperature storage conditions. The polyphenol content decreased initially and increased there after. When tubers were stored at 8-10°C the polyphenol content varied between 0.16 to 0.18 percent after 15 DAS and in tubers stored under frozen condition, it varied from 0.13 per cent to 0.16 per cent at 15 DAS up to which it retains its marketability. When tubers were stored in pit, 0.18 per cent polyphenol was recorded at 45 DAS, which was similar to that of freshly harvested tubers.

4.2.7 Ease of peeling

Table 23 shows the mean score for easiness of peeling. In coleus tubers, peeling became difficult as the storage period advanced irrespective of the method of storage. Under room temperature, peeling was rated as moderately easy (Score 3) up to 45 days of storage. In zero energy cool chamber the easiness of

Table 21. Sugar content of coleus tuber under different storage conditions and methods

Condition of storage	Method of storage	Sugar content (%)				
		Days after storage				
		0	15	30*	45*	60*
Room temperature	Open	0.88	1.18(34.09)	1.26(43.18)	1.23(39.77)	-
	Gunny bag	0.82	0.9819.51)	1.09(32.93)	1.03(25.61)	-
	Polythene lined gunny bag	0.99	0.98(1.00)	1.28(29.29)	1.26(27.27)	-
Zero energy cool chamber	Open	0.82	0.87(6.09)	0.97(18.29)	0.98(19.51)	1.01(23.17)
	Gunny bag	0.84	0.85(1.19)	0.86(23.80)	0.99(17.86)	1.10(30.95)
	Polythene lined gunny bag	0.90	0.94(4.44)	1.10(22.22)	1.15(27.72)	1.19(32.22)
8-10°C	Open	0.98	1.21(23.46)	-	-	-
	Gunny bag	1.01	1.36(34.65)	-	-	-
	Polythene lined gunny bag	1.00	1.39(39.00)	-	-	-
Deep freezer	Open	0.79	1.32(67.88)	-	-	-
	Gunny bag	0.82	1.11(35.36)	-	-	-
	Polythene lined gunny bag	0.88	1.20(36.36)	-	-	-
Room temperature		0.89	1.04(16.85)	1.21(35.95)	1.17(31.46)	-
Zero energy cool chamber		0.86	0.68(20.93)	0.94(9.30)	1.17(36.05)	1.10(27.91)
8-10°C		0.99	1.32(33.33)	-	-	-
Deep freezer		0.83	1.21(45.78)	-	-	-
	Open	0.83	1.08(30.12)	1.12(34.94)	1.12(34.94)	-
	Gunny bag	0.83	1.03(24.09)	0.98(18.07)	1.01(21.69)	-
	Polythene lined gunny bag	0.88	1.07(21.59)	1.19(35.23)	1.21(37.50)	-
	Pit	0.87	0.96(10.34)	1.12(28.73)	1.15(32.18)	-
CD for condition of storage		0.02	0.11	-	-	-
CD for method of storage		0.02	0.09	-	-	-
CD for methods within condition		0.04	0.19	-	-	-

* Values are not analysed statistically. Values in parentheses indicate percentage increase of sugar content

Table 22. Polyphenol content of coleus tuber under different storage conditions and methods

Condition of storage	Method of storage	Polyphenol content (%)				
		Days after storage				
		0	15	30*	45*	60*
Room temperature	Open	0.21	0.20	0.22	0.19	-
	Gunny bag	0.19	0.18	0.21	0.19	-
	Polythene lined gunny bag	0.18	0.13	0.13	0.17	-
Zero energy cool chamber	Open	0.18	0.16	0.15	0.18	0.14
	Gunny bag	0.17	0.17	0.15	0.17	0.13
	Polythene lined gunny bag	0.18	0.17	0.16	0.16	0.14
8-10°C	Open	0.17	0.18	-	-	-
	Gunny bag	0.19	0.16	-	-	-
	Polythene lined gunny bag	0.18	0.16	-	-	-
Deep freezer	Open	0.20	0.16	-	-	-
	Gunny bag	0.17	0.13	-	-	-
	Polythene lined gunny bag	0.19	0.16	-	-	-
Room temperature		0.19	0.17	0.19	0.18	-
Zero energy cool chamber		0.18	0.17	0.16	0.17	0.14
8-10°C		0.18	0.16	-	-	-
Deep freezer		0.18	0.15	-	-	-
	Open	0.19	0.17	0.19	0.19	-
	Gunny bag	0.18	0.16	0.18	0.18	-
	Polythene lined gunny bag	0.18	0.16	0.15	0.17	-
	Pit	0.18	0.17	0.18	0.18	-
CD for condition of storage		0.01	0.01	-	-	-
CD for method of storage		0.01	0.01	-	-	-
CD for methods within condition		0.02	0.02	-	-	-

* Values are not analysed statistically

Table 23. Ease of peeling of coleus tuber under different storage conditions and methods

Condition of storage	Method of storage	Mean score value				
		Days after storage				
		0	15	30	45	60
Room temperature	Open	1	1	2	3	-
	Gunny bag	1	2	2	3	-
	Polythene lined gunny bag	1	2	2	3	-
Zero energy cool chamber	Open	1	2	2	2	2
	Gunny bag	1	2	2	2	2
	Polythene lined gunny bag	1	2	2	2	2
8-10°C	Open	1	3	-	-	-
	Gunny bag	1	3	-	-	-
	Polythene lined gunny bag	1	3	-	-	-
Deep freezer	Open	1	3	-	-	-
	Gunny bag	1	3	-	-	-
	Polythene lined gunny bag	1	3	-	-	-
	Pit	1	2	2	3	-

Score: 1. Very easy. 2. Easy. 3. Moderately easy. 4. Difficult. 5. Very difficult peeling extended up to 60 DAS. Under low temperature peeling of tubers became very difficult after 15 days of storage. Tubers stored in pit could be peeled with moderate easiness after 45 DAS.

4.2.8 Tuber colour

A change in tuber colour during different storage conditions is shown in Table 24. The colour changed from light brown to brown under room temperature, zero energy cool chamber and pit storage. Tuber turned dark brown under low temperature storage (8-10°C and frozen).

4.2.9 Sensory quality

The initial score of the sample was seven; from this sample different lots were kept under varying storage conditions. Sensory qualities of these stored tubers were assessed adopting ranking technique and analysed using Kruskal Wallis one-way Anova. There was no significant difference within the storage method (different types of packing) and so comparison was done among the different storage conditions.

4.2.9.1 Colour

The mean score for the coleus tubers at different intervals of storage is given in Table 25. Tubers stored in zero energy cool chambers recorded the score of 6.83 at 60 DAS stage up to which it remained marketable. Room temperature was second best for colour (the score value showed 6.5 at the 45 DAS stage up to which it could be stored). Tubers stored in low temperature conditions (8-10°C and frozen) scored low values for colour. Tubers stored in pit had comparable colour to that stored under room temperature conditions.

4.2.9.2 Appearance

Table 25a shows the appearance of tubers stored under different conditions. Storage under zero energy cool chamber condition had better appearance than other methods with score value of 6.83 at 60 DAS stage. Under room temperature

Table 24. Changes of tuber colour under different storage conditions and methods

Condition of storage	Method of storage	Days after storage				
		0	15	30	45	60
Room temperature	Open	Light Brown	Light Brown	Light Brown	Brown	-
	Gunny bag	"	"	"	"	-
	Polythene lined gunny bag	"	"	"	"	-
Zero energy cool chamber	Open	"	"	"	"	Brown
	Gunny bag	"	"	"	"	"
	Polythene lined gunny bag	"	"	"	"	"
8-10°C	Open	"	Brown	Dark Brown	-	-
	Gunny bag	"	"	"	-	-
	Polythene lined gunny bag	"	"	"	-	-
Deep freezer	Open	"	"	"	-	-
	Gunny bag	"	"	"	-	-
	Polythene lined gunny bag	"	"	"	-	-
	Pit	"	Light Brown	Light Brown	Brown	-

Table 25. Evaluation of coleus tuber stored under different conditions based on colour

Storage condition	Days after storage				
	0	15	30	45	60
Room temperature	-	6.80	7.33	6.50	-
Zero energy cool chamber	-	7.33	7.17	7.17	6.83
8-10°C	-	6.00	-	-	-
Deep freezer	-	5.80	-	-	-
Pit	-	6.72	7.00	6.65	-
Kruskal Wallis H (5%)	-	32.35*	13.66*	18.18*	-

* Values differed significantly at 5% level

Table 25a. Evaluation of coleus tuber stored under different conditions based on appearance

Storage condition	Days after storage				
	0	15	30	45	60
Room temperature	-	7.50	7.17	6.67	-
Zero energy cool chamber	-	7.00	8.00	7.00	6.83
8-10°C	-	6.33	-	-	-
Deep freezer	-	6.17	-	-	-
Pit	-	6.72	7.25	6.52	-
Kruskal Wallis H (5%)	-	5.93	16.74*	18.05*	-

* Values differed significantly at 5% level

conditions a score of 6.67 was recorded at 45 DAS stage. Low temperature storage resulted in poor appearance for the produce. Tubers stored in pit were ranked in between low temperature storage and room temperature storage.

4.2.9.3 Texture

Scoring of texture is shown in Table 25b. Tubers stored under zero energy cool chamber showed better textural qualities (score 6.5 at 60 DAS stage). Storage under room temperature was second best (score 6.67 at 45 DAS stage). Storage at low temperature resulted in poor textural qualities. Tubers stored in pit were ranked on par with those stored at room temperature.

4.2.9.4 Aroma

Table 25c shows the aroma of the coleus tubers stored under different condition. Storage under zero energy cool chamber condition retained aroma (score 7 at 60 DAS). Room temperature storage was second best with score 6.67 at 45 DAS stage. Tubers stored under low temperature had poor aroma.

4.2.9.5 Taste

Scoring based on taste of stored tubers after cooking is shown in Table 25d. Higher ranking was given to tubers stored under zero energy cool chamber followed by room temperature storage. A score of 5.67 (at 60 DAS stage) was awarded to tubers stored under zero energy cool chamber and 6.17 for tubers stored under room temperature for 45 DAS stage. Low temperature storage resulted in poor taste (score value low).

4.2.9.6 Overall acceptability

Table 25e shows the overall acceptability of the tubers stored under different conditions. The acceptability was high when stored under zero energy cool chamber followed by room temperature.

Table 25b. Evaluation of coleus tuber stored under different conditions based on texture

Storage condition	Days after storage				
	0	15	30	45	60
Room temperature	-	7.00	6.67	6.67	-
Zero energy cool chamber	-	7.33	7.00	6.62	6.50
8-10°C	-	5.67	-	-	-
Deep freezer	-	5.67	-	-	-
Pit	-	6.92	6.81	5.95	-
Kruskal Wallis H (5%)	-	13.15*	13.50*	15.42*	-

* Values differed significantly at 5% level

Table 25c. Evaluation of coleus tuber stored under different conditions based on aroma

Storage condition	Days after storage				
	0	15	30	45	60
Room temperature	-	7.00	7.00	6.67	-
Zero energy cool chamber	-	7.17	7.50	6.50	7.00
8-10°C	-	5.50	-	-	-
Deep freezer	-	6.00	-	-	-
Pit	-	6.90	7.00	6.00	-
Kruskal Wallis H (5%)	-	14.88*	16.49*	15.86*	-

* Values differed significantly at 5% level

Table 25d. Evaluation of coleus tuber stored under different conditions based on taste

Storage condition	Days after storage				
	0	15	30	45	60
Room temperature	-	6.17	6.50	6.17	-
Zero energy cool chamber	-	7.17	6.83	5.67	5.67
8-10°C	-	5.67	-	-	-
Deep freezer	-	5.33	-	-	-
Pit	-	6.92	7.00	5.75	-
Kruskal Wallis H (5%)	-	10.40*	19.59*	17.04*	-

* Values differed significantly at 5% level

Table 25e. Evaluation of coleus tuber stored under different conditions based on overall acceptability

Storage condition	Days after storage				
	0	15	30	45	60
Room temperature	-	7.00	7.17	6.67	-
Zero energy cool chamber	-	7.00	7.83	6.67	6.67
8-10°C	-	5.83	-	-	-
Deep freezer	-	6.33	-	-	-
Pit	-	6.50	7.00	6.52	-
Kruskal Wallis H (5%)	-	6.08	17.78*	13.17*	-

* Values differed significantly at 5% level

4.3 STORAGE OF MINIMALLY PROCESSED COLEUS TUBERS

Minimally processed vegetables are products that have attributes of convenience and fresh like quality. An attempt was made to store minimally processed coleus tubers under different conditions of storage.

4.3.1 Spoilage of minimally processed tubers on storage

Data on spoilage of minimally processed coleus tubers stored under different storage conditions is given in Table 26. Among the three minimal processing operations, the peeled tubers without any blanching (or) steeping treatment could be stored for 2 days with minimum spoilage at 8-10°C. Peeling followed by blanching in hot water and peeling followed by steeping in KMS were the two operations compared. Spoilage on storage after peeling recorded at 8-10°C storage temperature was 9.33 per cent after 24 hours and 17.67 per cent in 48 hours. The spoilage was high under room temperature condition compared to zero energy cool chamber (44.67 and 31.67 per cent respectively at 24 hours). Minimal processing involving peeling followed by blanching in hot water and peeling followed by steeping in KMS showed 50 per cent spoilage within 24 hours and 100 per cent spoilage 48 hours under the different storage conditions.

4.3.2 Colour changes

A colour change of minimally processed coleus tuber stored under different conditions is shown in Table 27. Tuber colour after peeling changed from cream to dark brown. Light brown colour was maintained up to 48 hours when tubers were stored at 8-10°C storage temperature.

4.4 STORAGE STUDIES OF DEHYDRATED COLEUS TUBERS

4.4.1 Driage

Driage of coleus tuber under sun drying and hot air drying methods is shown in Table 28. Recovery after sun drying of 10 kg fresh tubers (for 13-14

Table 26. Spoilage of minimally processed coleus tuber stored under different condition

Minimal processing operation	Storage condition	Spoilage (%)		
		Hours after storage		
		0	24	48
Peeling	Room temperature	-	44.67	59.33
	Zero energy cool chamber	-	31.67	56.67
	8-10°C	-	9.33	17.67
Peeling followed by blanching in hot water	Room temperature	-	80.00	100.00
	Zero energy cool chamber	-	78.33	100.00
	8-10°C	-	80.00	100.00
Peeling followed by steeping in KMS	Room temperature	-	63.33	100.00
	Zero energy cool chamber	-	55.00	100.00
	8-10°C	-	46.67	100.00
	Room temperature	-	62.67	-
	Zero energy cool chamber	-	55.00	-
	8-10°C	-	45.33	-
Peeling		-	28.56	44.55
Peeling followed by blanching in hot water		-	79.44	100.00
Peeling followed by steeping in KMS		-	55.00	100.00
CD for the operation			4.92	1.55
CD for method of storage			5.02	2.04
CD for interaction of methods within operation			8.69	3.52

Table 27. Colour changes of minimally processed coleus tuber stored under different condition

Minimal processing operation	Storage condition	Colour changes		
		Hours after storage		
		0	24	48
Peeling	Room temperature	Cream	Brown	Dark Brown
	Zero energy cool chamber	,,	,,	,,
	8-10°C	,,	Light brown	Light brown
Peeling followed by blanching in hot water	Room temperature	Yellowish cream	Brown	Dark brown
	Zero energy cool chamber	,,	,,	,,
	8-10°C	,,	,,	,,
Peeling followed by steeping in KMS	Room temperature	Cream	Brown	Dark brown
	Zero energy cool chamber	,,	,,	,,
	8-10°C	,,	,,	,,

Table 28. Driage of dehydrated coleus tuber under different drying conditions

Drying condition	Initial (kg)	Final (kg)	Driage (%)
Sun drying (13-14 hrs)	10	3.7	63
Hot air drying (8-9 hrs)	10	2.5	75

hours) was 3.7 kg (63 per cent driage). With hot air oven drying the recovery was 2.5 kg (75 per cent driage).

4.4.2 Rehydration ratio

Rehydration ratio in hot air oven dried product ranged from 3.03 at initial stage to 3.28 at 60 DAS stage. In the case of sun dried product the rehydration ratio ranged from 3.04 at initial stage to 2.92 at 60 DAS stage. Appearance of the rehydrated products was poor in sun-dried product compared to oven-dried product. There was significant difference in rehydration ratio between sun dried and oven dried products.

4.4.3 Equilibrium relative humidity (ERH)

Table 30 and Fig 12 shows the ERH of the dehydrated coleus tuber. Moisture loss was observed when dehydrated tubers were stored at 40 and 60 per cent relative humidity. At 80 per cent relative humidity, a gain in weight of 1.7 per cent and 2.9 per cent was recorded for sun dried and oven dried products, respectively. The equilibrium relative humidity of sun-dried product was calculated as 73 per cent and for hot air oven dried product it was 71 per cent.

4.4.4 Spoilage of dehydrated products

The spoilage of dehydrated products was assessed based on colour changes after cooking. This change in colour to dark brown after cooking occurred in tubers 90 days after storage. But the other spoilage factors like mould growth was observed only after 6 months.

4.4.5 Sensory qualities of rehydrated tubers

Data on sensory evaluation of rehydrated coleus tubers is shown in Table 31. Overall acceptability was poor for the dehydrated, stored product due to its poor appearance and quality. Among the methods compared, sensory qualities of rehydrated tubers were rated high for hot air dried products stored in polythene lined gunny bags.

Table 29. Rehydration ratio of dehydrated coleus tuber stored under different conditions.

Dehydration method	Condition of storage	Rehydration ratio			
		Days after storage			
		0	30	60	90
Sun drying	Gunny bag	3.01	2.85	2.78	2.71
	Polythene lined gunny bag	3.06	2.76	3.06	2.95
Hot air oven drying (60°C)	Gunny bag	2.90	3.17	3.22	2.98
	Polythene lined gunny bag	3.16	3.32	3.34	3.16
Sun drying		3.04	2.81	2.92	2.83
Hot air drying		3.03	3.25	3.28	3.07
	Gunny bag	2.95	3.01	3.00	2.85
	Polythene lined gunny bag	3.11	3.04	3.20	3.06
CD for method of drying		0.01	0.02	0.01	0.01
CD for condition of storage		0.01	0.02	0.01	0.01
CD for mehtod of drying within condition of storage		0.01	0.03	0.02	0.02

Table 30. Equalibrium relative humidity of coleus tubers dehydrated under different drying conditions

Relative humidity (%)	Sundried product (Gain/loss/g)	Oven dried product (Gain/loss/g)
40	-0.054	-0.062
60	-0.027	-0.036
80	+0.017	+0.029
ERH	73%	71%

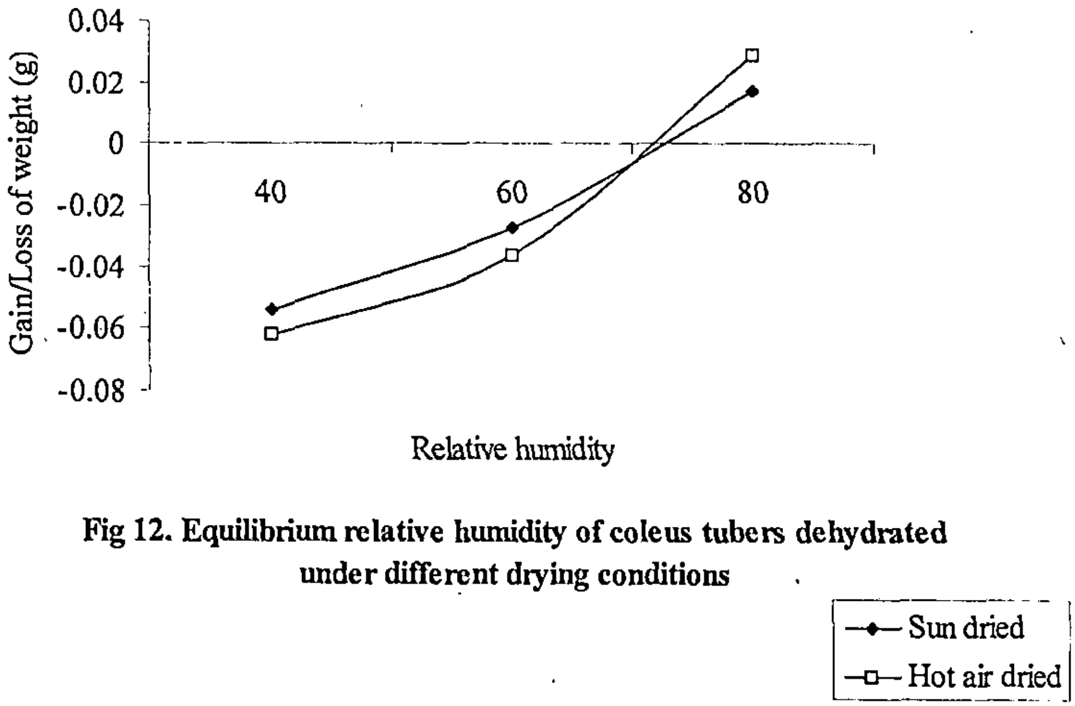

Fig 12. Equilibrium relative humidity of coleus tubers dehydrated under different drying conditions

Table 31. Sensory evaluation of rehydrated coleus tubers

Sensory characters	Mean sensory value															
	Days after storage															
	Sun dried								Hot air dried							
	0		30		60		90		0		30		60		90	
	GB	PLGB	GB	PLGB	GB	PLGB	GB	PLGB	GB	PLGB	GB	PLGB	GB	PLGB	GB	PLGB
Colour	5.2	5.4	4.2	4.2	4.0	5.0	2.4	2.4	6.4	6.6	5.0	5.0	4.6	5.0	3.2	2.6
Appearance	4.6	5.0	4.4	4.3	4.2	3.8	2.4	2.2	5.8	7.2	4.8	5.0	4.4	5.0	2.4	2.2
Texture	5.2	7.2	5.8	4.8	5.0	5.0	2.8	2.6	6.6	6.4	5.6	6.0	5.2	5.4	2.6	2.2
Aroma	5.0	5.4	5.0	4.2	4.4	3.8	2.8	2.6	6.2	6.4	5.8	5.6	4.2	4.6	3.0	2.4
Taste	4.4	4.0	4.0	3.4	2.0	1.8	1.8	1.8	5.4	5.6	5.0	5.2	2.6	2.6	2.4	2.2
Overall acceptability	4.8	5.2	4.0	2.0	2.0	1.8	1.8	1.8	5.8	5.8	5.0	5.4	3.2	3.2	1.8	1.8

Discussion

5. DISCUSSION

5.1 BIOMASS ACCUMULATION

Biomass accumulation in coleus was examined with a view to explain the pattern of tuber development and to identify the initial stages in tuber development. Whole plant samples drawn at regular intervals from 60 DAT onwards was analysed to describe the pattern of biomass accumulation and partitioning. Peak fresh weight was recorded at 75-90 DAT stage. This stage can be called as the peak stage for the above ground canopy development. This is the stage of initiation of tuber growth. High rate of growth was also recorded during this phase. In tapioca Ramanujam and Birader (1987) found that initial dry matter accumulation was in leaves and tuber bulking started from the 4^{th} month onwards. In *Amorphophallus* also dry matter accumulation in above ground portion increased up to 6^{th} month (Nair and Mohankumar, 1991).

The leaf biomass had attained a peak at 90 DAT stage, when leaves constituted nearly 40 per cent of total fresh biomass and leaf and stem together constituted almost 78 per cent of total biomass. Proportion of leaf dry matter to the total dry matter indicated a decline from 60-75 DAT stage onwards to the harvest stage. Domination of shoot growth during the initial phases of growth had been recorded in sweet potato also (Ravi *et al.*, 2000).

Dry matter in the stem increased up to 105 DAT stage. The decline in total fresh biomass observed after 90 DAT could be explained on the basis of movement of photosynthates to the tuber and accumulation in tuber with reduced moisture content.

Variation was observed among varieties in terms of root biomass and proportion of root dry matter to total dry matter. Variation in shoot/root growth pattern between varieties would reflect on yield as well.

Tuber formation was initiated from 90 DAT stage. There was a linear increase in tuber fresh weight up to 135 DAT.

The tuber development in coleus followed a sigmoid pattern with an initial increasing phase reaching a peak by 150 DAT when the crop attained harvest maturity and the above ground parts dry up. Beyond this stage there is a decline in tuber biomass.

The growth pattern in coleus observed from the study could be divided into three phases. The first phase between planting to 90 DAT was a phase of rapid vegetative growth when the photosynthates were partitioned to stem and leaves form a well-developed canopy. The second phase initiated at 90 DAT is characterised by the tuber growth taking the lead and major portion of photosynthates moving on to the tubers. This phase continued up to 150 DAT till the tubers matured. During this phase there is a sharp decline in the dry matter percent in the above ground parts. Beyond 150 DAT there is a decline in the total biomass. Absolute growth rate for the above ground parts was higher at 60-90 DAT stages. By this stage plants had developed sufficient canopy structure to serve as source of photosynthates for tuber development. The period between 90 DAT and 120 DAT is one where the tuber growth predominated over foliage and root growth. During this stage biomass accumulation of stem, tuber and leaf growth rate was near static. During the third phase, which commenced from 120 DAT, there was a linear increase in tuber biomass, which reached a plateau at harvest maturity (150 DAT). During this phase there was a decline in stem, leaf and root biomass. The pattern of biomass partitioning is similar to crops such as cassava, sweet potato and yams (Ramanujam, 1991; Mannan *et al.*, 1992 and Nair and Mohankumar, 1991). At harvest stage 70-79 per cent of total biomass was present in the tubers and at this stage varieties did not show significant difference. At 135 DAT stage varieties had indicated significant difference in terms of tuber biomass thus indicating that the tuber yield is a function of total biomass produced and the proportion of total biomass partitioned to the tubers is similar in the varieties evaluated.

5.2 GROWTH OF TUBERS

Formation of sink for accumulation of biomass is a major factor in deciding the pattern of partitioning. In coleus the biomass accumulation in tubers proceed both by an increase in the number of tubers and by increase in the size/weight of the tubers already formed. The number of tubers increased from an average 0.07 at 90 DAT to 11.2 at harvest stage across the varieties. Tuber growth rate was highest during the first fortnight after initiation, there after the increase in length and diameter was gradual but continuous till harvest stage. Both source and sink potential is important determining the yield. Ravi (2000) opined that source potential is more limiting than sink during early growth period and they are equally important in determining the tuber yield at later period after formation of tubers. More growth activity in the above ground parts could result in competition reducing the tuber yield.

5.3 QUALITATIVE CHANGES DURING GROWTH OF TUBERS

The specific gravity of tubers during the formation stage was less than one. With the commencement of starch accumulation the specific gravity increased to >1 and remained so throughout the growth period. The change in specific gravity could be attributed to the accumulation of starch in the tubers. The increase in starch content also continued throughout the growth period. Soluble sugars peaked at 135 DAT and declined thereafter. Variation in sugar content had been gradual and had reached its peak at 135 DAT stage. During the maturation phase the soluble sugar content had declined. Vijayakumar and Shanmughavelu (1985) in their studies have observed that the total sugar increased till 120th day and declined later and attributed it to the progressive increase in starch content.

Change in polyphenol content was also gradual and tubers showed highest polyphenol content at mature stage.

5.4 MATURITY INDICES

Tuber formation was initiated by 90 DAT stage and the growth of tubers continued till 150 DAT by which period the stem and foliage dried up. The drying up of above ground parts, darkening of tuber skin colour and drop in the sugar content of tubers could be considered as maturity indices. The peel colour changed from light brown to deep/dark brown with maturation and the flesh colour changed from yellowish cream to whitish cream.

Nematode infestation is a major problem in coleus production. The appearance as well as cooking quality is affected by the nematode infestation. The analysis of starch, sugar and phenols had indicated that there is a reduction in starch and increase in both sugar and polyphenol levels. The deformation of tubers could be due to the non-uniform distribution of photosynthates in the cells. The involvement of hormonal factors in this have to be looked into.

5.5 SENSORY EVALUATION

Sensory qualities including colour, appearance, texture, aroma, taste and overall acceptability of cooked tubers had shown that highest scores are given for fully mature tubers. Retaining the crop up to full maturity is thus necessary to develop characteristic quality of the crop.

5.6 STORAGE OF COLEUS TUBERS

Experiments conducted to assess the storage life of coleus tubers under different conditions of packing and storage indicated that both factors influence the storage life. Sprouting of tubers, microbial decay, weight loss due to moisture loss and sensory qualities are affected by storage.

Stored tubers started sprouting by January irrespective of the storage condition and harvest time unless they are otherwise spoiled. Variation was however noticed in the sprouting percentage. The conditions available under zero energy cool chamber was found favourable for longer storage. Here only 4-8 per cent sprouting was recorded after 60 days in storage (plate 5). Variation in sprouting due to storage condition, variety, tuber weight etc. is known to influence sprouting of tubers in potato (Puskarnath, 1976; Banerjee, 1994). In coleus also the type of storage, time of harvest and variety influenced the sprouting behaviour. The traditional practice followed for storage of tubers by keeping them covered with soil in a pit was effective in coleus also but the sprouting of tubers could not be prevented in this case as well.

Spoilage of tubers by decay due to microbial infestation was more serious when the tubers were stored under packed condition. After one-month storage under room temperature, spoilage began when tubers were kept in gunny bags/polythene lined gunny bags. The improvement of gaseous exchange in storage under packed condition could have resulted in build up of humidity and temperature within the microenvironment resulting in increased microbial activity. Spoilage under low temperature and freeze storage condition is more due to physiological factors and freeze injury. Most of the tropical tubers like tapioca, sweet potato etc. are known to have poor storage under low temperature conditions, chilling conditions make sweet potato roots more susceptible to microbes (Arine and Smith, 1980). Increased sensitivity to pectic enzymes and reduced synthase of phytoalanine has been cited as possible reasons by the authors.

Quantitative loss due to PLW is an important factor in storage. As a commodity, which is physiologically very active, coleus tubers suffer fairly high PLW on storage. The rate of loss of moisture is related to the condition of storage. Storage under open conditions without any packing had resulted in 10-16 per cent weight loss. PLW was comparatively low under zero energy cool chamber storage. Evaporative cool storage technique was advantageous for storage of potato also where PLW was found to be less (Kaul and Sukumaran, 1984). PLW could also be influenced by sprouting and spoilage apart from moisture loss.

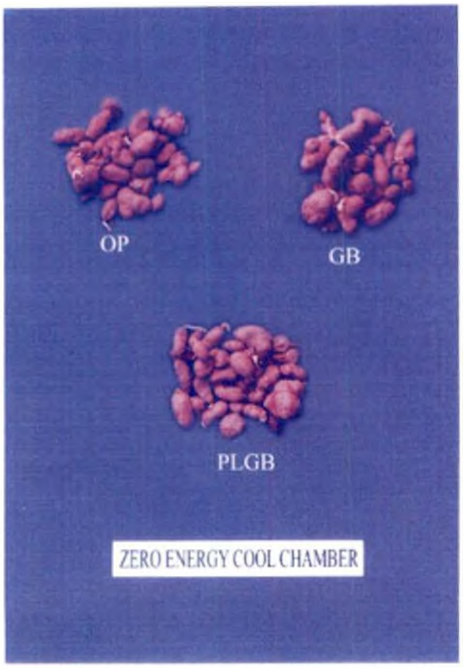

Plate 5. Coleus tubers stored under zero energy cool chamber at 60 DAS

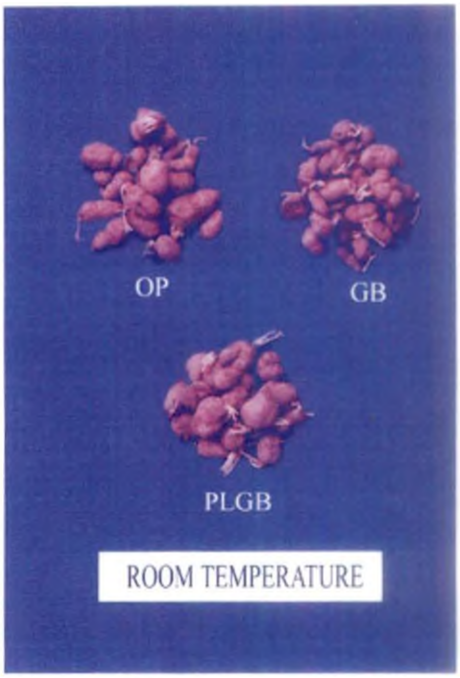

Plate 6. Coleus tubers stored under room temperature at 45 DAS

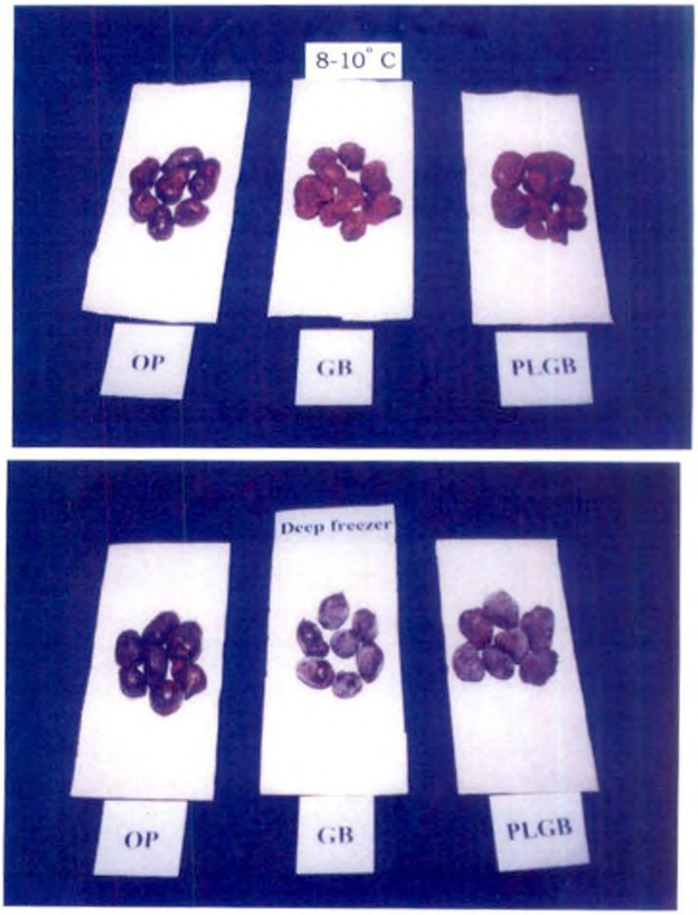

Plate 7. Coleus tubers stored under low temperature (8-10^{0} C and deep freezer) at 25 DAS
OP - Open; GB - Gunny bag
PLGB - Polythene lined gunny bag

Taking into consideration of the factors like sprouting, decay and spoilage as well as PLW, storage of coleus under zero energy cool chamber conditions could be advantages over storage under open conditions.

5.7 CHANGES DURING STORAGE

Changes in composition during storage due to physiological and microbial activity are the other important factors in the quality of stored produce. Enzyme involved changes in starch and sugar influence the cooking quality of the produce. In coleus the starch content decreased and soluble sugars increased marginally during storage due to slow respiration. In potato, cassava, dioscorea etc. also similar trend had been reported while in storage (Khurana *et al.*, 1985; Biemelt *et al.*, 2000; Maini and Balagopal, 1978). Low temperature storage increased sweetness in potato (Pushkarnath, 1976).

The phenolic substances present in coleus tubers did not show definite pattern of variation in storage. Contradictory findings have been reported in potato by Tripathi and Verma, (1975) and Uppel *et al.*, (1978). While Tripathi and Verma observed a decrease in total phenolic substances in peel and pulp of potatoes stored under ambient conditions, Uppel *et al.*, (1978) reported 100 per cent increase of phenolic content when stored for 5 months under ambient/cold storage conditions. In cassava a decrease in total phenols was reported under storage by Rickard (1981). Here also erratic changes have been reported by Balagopalan and Padmaja (1985). In the present study coleus tubers have shown an initial decrease followed by an increase in total phenols when the tubers were stored under low temperature conditions.

5.8 CHANGES IN OTHER QUALITY PARAMETERS

Peeling operations in coleus is cumbersome. Fresh tubers can be peeled easily with mild abration but the process becomes difficult with moisture loss. Assessment of ease of peeling of stored tubers has shown that the peeling process

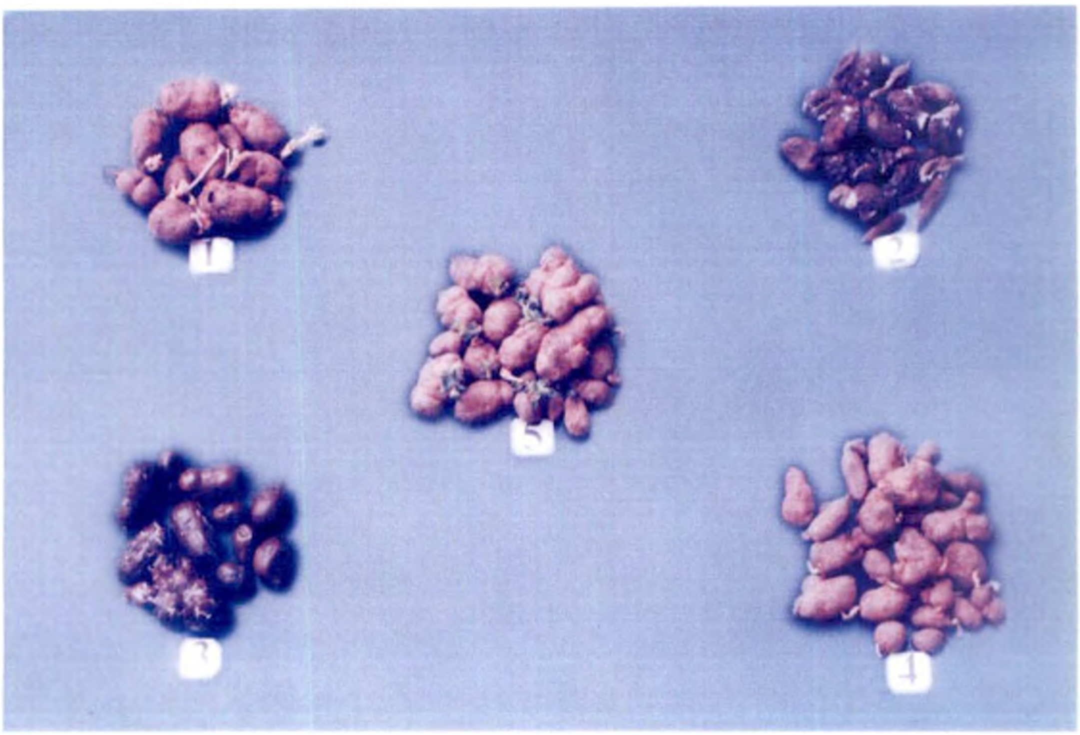

Plate 8. Comparison of coleus tubers stored under different storage conditions at 60 DAS

1. Tubers stored under pit
2. Tubers stored under deep freezer
3. Tubers stored under 8-10^0 C
4. Tubers stored under zero energy cool chamber
5. Tubers stored under room temperature

was difficult in stored tubers irrespective of the method of storage. Among the storage method, tubers stored in zero energy cool chamber was rated as fairly easy for peeling apparently due to lower level of moisture loss from the produce. When tubers were stored under low temperature, there was more shrinkage and peeling was more cumbersome.

Tuber colour and sensory quality also affects marketability of the produce. Low temperature storage resulted in darkening of tubers, which reduced the consumer appeal. Slight variation was also noted in the textural quality of stored tubers after cooking. Changes in composition especially variation in starch content could have influenced the cooking quality of tubers.

Retention of aroma during storage is important since the characteristic quality of coleus is its aroma. Storage under zero energy cool chamber conditions retained the aroma of tubers better compared to room temperature storage. The important components that contribute to the aroma have been reported as α-thujone and β-farnascene though the temperature related changes in these constituents can not documented. Conditions available under zero energy cool chamber could have retained these constituents resulting in better retention of aroma. The overall acceptability was more for the produce stored under zero energy cool chamber.

5.9 MINIMAL PROCESSING OF COLEUS

Convenience food is becoming more popular among the urban and semi urban population. Ready to cook vegetables are gaining acceptance among housewives. Coleus, with the inherent difficulty in peeling is one where minimally processed ready to cook form could be of great relief to the consumers. Storability of peeled and stored coleus tubers was assessed in the present study. Peeled and sliced tubers could be stored with minimum spoilage at 8-10°C for two days. Discolouration, browning, oozing and off flavour development caused spoilage of stored materials. Presence of moisture and phenolic constituents could have influenced the spoilage. Use of antioxidants or edible coating materials could be effective (Li-Paiyin and Barth, 1998). Blanching and dipping in sulphurdioxide media did not improve the storage. Infact the quality of material and storage life was less in blanched produce. Starch being the major constituent, blanching could have enhanced the chances of microbial growth and spoilage.

5.10 DEHYDRATION OF COLEUS TUBERS

Coleus tuber contains moisture will above 85 per cent. Dehydration of tubers is a widely adopted method for preservation in tapioca, arrowroot, potato etc. Dehydration of coleus tubers after slicing had given a dull coloured product, which lacked consumer acceptance (plate 10). The phenolic substances present in the tuber caused discolouration. Storability of the dehydrated produce was however good. Rehydrated product had poor appearance and overall acceptability. Comparisons were made between sun dried and oven dried products. Better score was obtained for oven dried product. It implies that faster method of drying could be more effective in preventing discolouration. Use of antioxidants/additives to get better quality dehydrated produce have to be attempted.

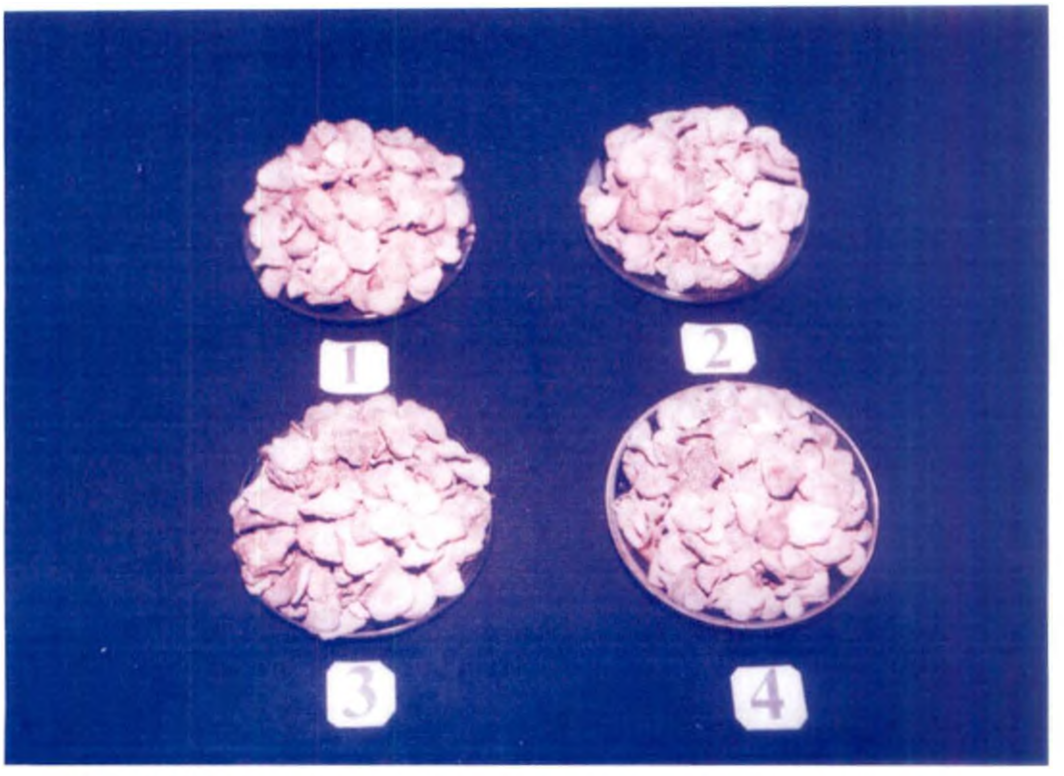

Plate 9. Dehydrated coleus tubers under different storage conditions

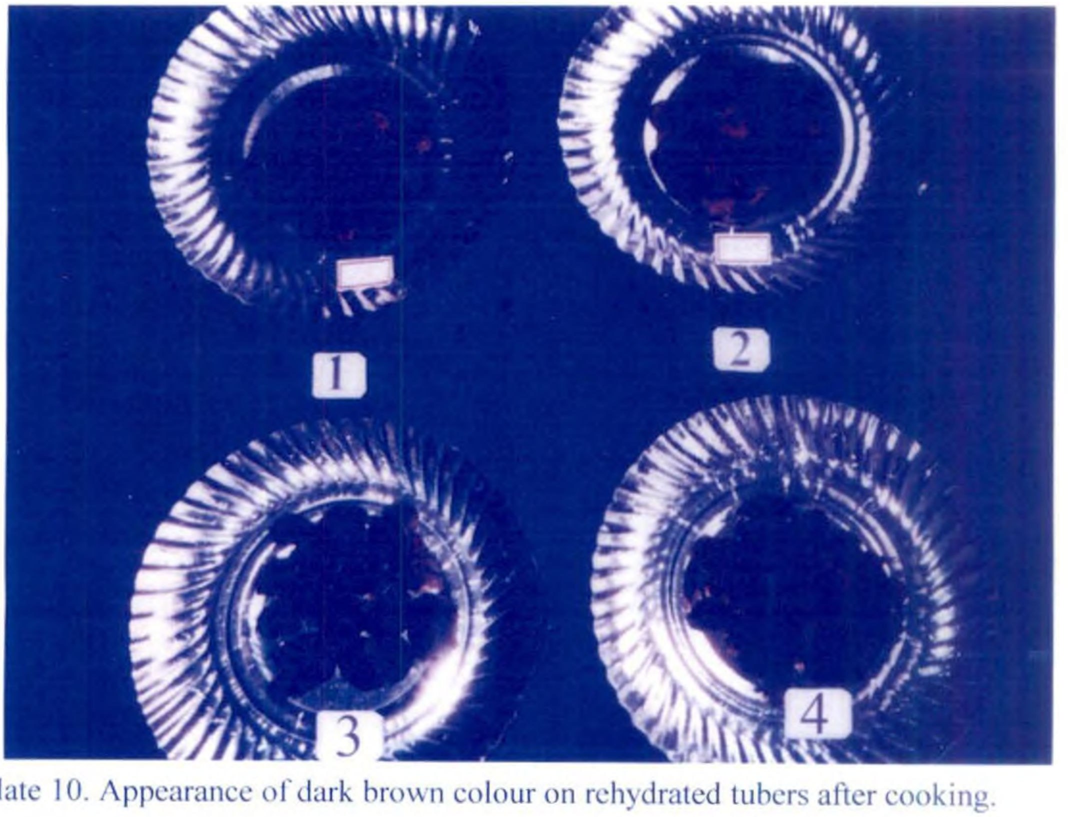

Plate 10. Appearance of dark brown colour on rehydrated tubers after cooking.

1. Sun dried dehydrated tubers stored under gunny bag.
2. Sun dried dehydrated tubers stored under polythene lined gunny bag.
3. Hot air oven dried dehydrated tubers stored under gunny bag.
4. Hot air oven dried dehydrated tubers stored under polythene lined gunny bag.

Summary

SUMMARY

Studies on the Quantitative and qualitative changes in coleus (*Solenostemon rotundifolius* (Poir) J.K.Morton) tubers during development and storage were carried out at Regional Agricultural Research Station, Pattambi and Department of Processing Technology, College of Horticulture, Vellanikkara, during 2001-'02. The objective of the study was to analyse changes in quantitative and qualitative characters of coleus tubers during development and storage, to examine the influence of different storage conditions on coleus tuber and to study the storage characters of minimally processed and dehydrated tubers.

Three varieties of coleus were raised in RBD with six replications. The observations on growth of plant were taken at fifteen day intervals from 60 days after transplanting till the final harvest and were analysed.

The results of the present investigation are summarised as below.

Growth pattern and Dry matter partitioning in coleus:

1. The total fresh biomass increased up to 90 days after transplanting in all the varieties. There after it declined. Among the three varieties, Sreedhara produced the highest total biomass compared to others. The absolute growth rate was maximum between 75-90 days after transplanting in variety Sreedhara and Nidhi, where as culture CP-74 showed the maximum absolute growth rate between 60-75 DAT.

2. The ratio of leaf biomass in terms of fresh weight to total biomass was high at 60 DAT stage in all the varieties.

3. More than 50 per cent of total dry matter was present in the leaves in all the varieties at 60 DAT.

4. The ratio of stem biomass in terms of fresh weight to the total biomass showed an increasing trend up to120 DAT stage, followed by a decline in all the varieties.

5. Stem dry matter increased up to 120 DAT in all the varieties.

6. The ratio of root biomass in terms of fresh weight to total biomass showed an increasing trend up to 120 DAT and then declined.

7. The pattern of accumulation of dry matter in root during different stages of growth showed a gradual increase up to 120 DAT followed by a declined.

8. The tuber biomass in terms of fresh weight to total biomass during different stages of growth showed an increasing trend till the final harvest (150 DAT) in all the varieties.

9. The tuber dry matter accumulation also showed an increasing trend up to 150 DAT (harvest stage). The absolute growth rate was highest between 135-150 DAT stage in all the varieties.

10. The total number of tuber was highest at the harvest stage in all the varieties.

11. The length, diameter, peel thickness and peel percentage was highest at the harvest stage (150 DAT) in all the varieties.

12. During the different stages of growth the peel colour changed from yellowish brown (150 DAT stage) and the flesh colour changed from yellowish cream to whitish cream during the same period.

13. The starch content of coleus tuber during development stage showed a gradual increase from 90 DAT to 150 DAT stage in all the varieties.

14. The soluble sugar content at different growth stages showed increasing trend up to 135 DAT and there after declined in all the varieties.

15. The pattern of accumulation of phenolic substances during growth of tubers showed an increasing trend up to the harvest stage in all the varieties.

16.Quality parameters of nematode infested tubers indicated higher level of sugars and polyphenols and lower starch content when compared to non-infested tubers.

17. The sensory qualities of tubers were maximum when the tubers were harvested at 150 DAT.

Storage studies

18. Sprouting started 30 days after storage in all the storage conditions except in low temperature (8-10^{0}c and frozen), where no sprouting was observed due to complete spoilage. High sprouting was observed in room temperature followed by storage in pits. Tubers stored in zero energy cool chamber showed minimum sprouting compared to other conditions of storage.

19. Spoilage was highest under low temperature storage (8-10^{o}c and frozen). Pit and zero energy cool chamber storage conditions were on par and were found to reduce spoilage. Minimum spoilage was observed in tubers stored under room temperature.

20. Minimum physiological loss in weight was observed in tubers stored under low temperature (8-10^{o}c and frozen) conditions followed by zero energy cool chamber and pit storage. Physiological loss in weight was higher in room temperature storage.

21. Sugar content showed an increasing trend during storage under all the storage conditions. The rate of change in sugar content was higher under low temperature storage followed by room temperature.

22. No definite pattern was indicated in the polyphenol content after storage.

23. Peeling was easier when the tuber was stored under zero energy cool chamber or pits. Storage under low temperature conditions made peeling difficult.

24. During storage, the colour changed from light brown to brown under room temperature, zero energy cool chamber and pit storage. Tubers turned to dark brown colour under low temperature conditions.

25. Tubers stored under zero energy cool chamber condition were found to be best for all sensory qualities like the colour, appearance, texture, aroma, taste and overall acceptability. Tubers stored under low temperature storage had poor quality.

26. Among the three minimal processing compared, the peeled tubers could be stored for two days with minimum spoilage at 8-10°C. Spoilage was 100 per cent with in two days in tubers stored after blanching or steeping in KMS.

27. Rehydration ratio was more in hot air oven dried tubers compared to sun-dried sample.

28. The equilibrium relative humidity of sun-dried product was 73 per cent and for hot air oven dried product it was 71 per cent.

29. The spoilage of dehydrated products was assessed based on colour changes after cooking. Over all acceptability was poor for the dehydrated, stored products. Among the methods compared, sensory qualities of rehydrated tubers were rated better for hot air dried products than sun dried one.

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QUANTITATIVE AND QUALITATIVE CHANGES IN COLEUS (*Solenostemon rotundifolius* (Poir) J.K. Morton) TUBERS DURING DEVELOPMENT AND STORAGE

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ABSTRACT OF THE THESIS

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ABSTRACT

Studies were conducted at Regional Agricultural Research Station, Pattambi and the College of Horticulture, Vellanikkara to analyse the quantitative and qualitative changes during development and storage of coleus tubers. During the development the total fresh biomass of the plant increased up to 90 days after transplanting in all the varieties. The absolute growth rate was highest between 75-90 days after transplanting. The leaf fresh biomass increased up to 60 DAT in all the varieties and at this stage more than 50 per cent of dry matter was present the leaves. The stem fresh biomass of stem increased up to 120 DAT, the fresh biomass of root also increased up to 120 DAT and the rate of accumulation of root dry matter was high up to 120 DAT. The fresh biomass of tuber and dry matter accumulation showed an increasing trend along with maturity of tubers. The higher growth rate was between 135-150 DAT stages. Total number of tubers, length, diameter, peel thickness and peel percentage were found to increase with maturity of tubers. The peel colour changed from yellowish brown to brown and the flesh colour changed from yellowish cream to whitish cream during maturation.

The starch and polyphenol content increased with the maturity of tubers, where as the soluble sugar increased up to 135 DAT and thereafter declined. The nematode infested tubers showed higher sugar and polyphenol content and lower starch content compared to non-infested one. The sensory evaluation indicated that the overall acceptability increased with the advancement of maturity.

Storage behaviour of coleus tuber was assessed under different conditions of storage. Sprouting and physiological loss in weight was lowest under the zero energy cool chamber storage. Room temperature and pit storage were rated next to zero energy cool chamber. The spoilage was minimum in tubers stored under room temperature followed by zero energy cool chamber. The starch content of tubers decreased and sugar content increased in storage.

No definite pattern was indicated in the polyphenol content during storage. Tubers turned dark brown under low temperature storage conditions. The tubers stored under zero energy cool chamber showed better sensory characters. Peeled tubers could be stored for two days with minimum spoilage at 8-10°C. Hot air oven dried product had a higher rehydration ratio and better sensory quality compared to sun dried one.