SCREENING GINGER (*Zingiber officinale* Rosc.) GENOTYPES UNDER DIFFERENT GROWING CONDITIONS AND FOR VALUE ADDITION

by
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(2015-22-003)

THESIS

Submitted in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY IN HORTICULTURE

Faculty of Agriculture
Kerala Agricultural University

DEPARTMENT OF PLANTATION CROPS AND SPICES
COLLEGE OF HORTICULTURE,
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VELLANIKKARA, THRISSUR- 680 656
KERALA, INDIA
2018

DECLARATION

I, hereby declare that the thesis entitled "**SCREENING GINGER (*Zingiber officinale* Rosc.) GENOTYPES UNDER DIFFERENT GROWING CONDITIONS AND FOR VALUE ADDITION**" is a bonafide record of research work done by me during the course of research and the thesis has not been 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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ACKNOWLEDGEMENT

Words are insufficient to express gratitude and indebtedness. Though, it is an attempt to remember the faces with a sense of gratitude. So many have been with me on the path traversed during the three year journey!

First and foremost, I bow my head before the Almighty God for his blessings, providing me favourable conditions, making me confident to move ahead at each step and enabling me to successfully complete the thesis work in time.

It is with immense pleasure I avail this opportunity to express my deep sense of whole hearted gratitude and indebtedness to my Major Advisor Dr. K. Krishnakumary, Professor, Department of Plantation crops and Spices, for her advice, ever present help, motherly guidance, valuable suggestions, constructive criticisms and above all, understanding and whole hearted co-operation rendered throughout the course of my study. I consider it as my fortune in having her guidance for my research work and my obligation to her lasts forever. I owe to her more than I care to admit.

I acknowledge the patronage bestowed upon me by the members of my advisory committee. I consider it as my privilege to express my gratitude to Dr. P. V. Nalini, Professor and Head, Department of Plantation crops and Spices for her constant support, valuable suggestions and cooperation throughout the research programme. I am deeply obliged to Dr. Jalaja S. Menon, Assistant Professor Department of Plantation crops and Spices, for her invaluable help, guidance and critical assessment throughout the period of work. I express my heartfelt thanks to Smt. Meagle Joseph, Associate Professor, Department of Processing Technology for her constant encouragement and support throughout the research programme. I express my gratitude to Dr. S. Krishnan, Professor and Head, Department of Agricultural Statistics for his help and guidance during the statistical analysis of data.

My heartfelt thanks to my beloved teachers Dr. Alice Kurian, Dr. V. S. Sujatha, Dr. B. Suma and Dr. P. Anitha for their encouragement, constant inspiration and advice rendered during the course of my study which helped in successful completion of this work. I am also extremely thankful to Dr. Saji Gomez and Dr. A. V. Santhoshkumar for their encouragement and moral support during the period.

I render my profuse thanks to Dr. C. George Thomas, Associate Dean, College of Horticulture, Vellanikkara. I am thankful to Dr. T. Girija, Professor and Head, Department of Plant Physiology for her immense help and guidance, especially during the physiological analysis. I wish to acknowledge the scientists and staff of Spices Board, Cochin and Kerala Forest Research Institute, Peechi for assisting me in doing biochemical analysis.

I am grateful to Mr. Sunil Nair, Farm officer, Department of Plantation crops and Spices; Sheena chechi, Research assistant, Department of Plant Physiology; Mrs. Jooby, Biochemist, Department of Processing Technology; I express my heartfelt thanks to

Devooty chechi, Chandrika chechi, Bindu chechi, Sindhu chechi, Sumi chechi , Rajan chettan, Vijayan chettan. Deepa chechi , Sajitha chechi, Daya chechi, Manisha chechi for their cooperation and immense help rendered during my research work

I am in dearth of words to express my sincere thanks to my classmate Mr. Vijaykumar B. N, seniors Mr. Vikram and Mr. Ajithkumar and Juniors Ms. Akoijam Ranjita Devi, Mr. Surendra Babu , Ms. Priyanka S. Chandran, Mrs. Surya Subin, Ms. Sruthy K., Ms. Geethumol Thankappan, Ms. Manisha Elsa Jacob, Ms. Anila Peter, Ms. Sreelakshmi, Ms. Shibana, Ms. Dharini ,Mr. Shankar Prasad, Ms.Megha, Ms. Anu ,Ms. Sarga and all my Ph. D batchmates for their help and support.

I express sincere thanks to my besties Mrs. Irene Elizebath John, Mrs. Shilpa Ramachandran, Ms. Vandana G. Pai, Mrs. Aryamba Karthish, Mr. Sreejith Kumar V. P, Mr. Dipin M. N and Ms. Sachana P. C for their words of advice, encouragement and timely help whenever approached.

I owe special thanks to staff of College of Horticulture Library; Kerala Agricultural University Central Library and Students' Computer Club. The financial aid and technical support provided by Kerala Agricultural University and MANF is also highly acknowledged.

I reveal my extreme sense of regards to my father, Mr. K. J. Mathew; my mother, Mrs. Thresiamma Mathew; my brothers, Mr. Jeffin Mathew s and Mr. Geordy Mathew for their sacrifices, moral support, love, concern, prayers and blessings.

Special thanks to my beloved friends Mr. Jibin M. S., Mr. Jithin M. S., Mrs. Ria Sebastian and Mr. Alphin Chacko.

A word of apology to those whom I forgot to mention here. Once again I express my sincere thanks to all those who supported me in one way or another and tried to make it a success.

Nimisha Mathews

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INTRODUCTION

1. INTRODUCTION

Ginger is an important commercial spice crop grown in India for its culinary and wide range of medicinal uses and is considered as an essential component of the kitchen pharmacy. Essential oil and oleoresin from ginger are the valuable products responsible for the characteristic flavour and pungency. Gingerols, the pungent principle of ginger are biologically the most active component that makes significant contribution towards the medicinal applications of ginger as anti-inflammatory, cardiotonic and cancer chemopreventive. It is 'generally recognized as safe' by the Food and Drug Administration (FDA) of the United States and has gained considerable attention as a botanical dietary supplement in developed countries, opening ample export potential. The refreshing pleasant aroma and carminative property of ginger make it an indispensable ingredient of food processing industry.

Advantage of growing crops in rain shelter and polyhouse was reported in many crops whereas such information is lacking in ginger. In Kerala, Ginger is normally cultivated as a rainfed crop and is affected by many diseases especially rhizome rot caused by *Pythium aphanidermatum*. Soft rot reduces the potential yield to a great extent and continuous and heavy rain increases the intensity of disease. In Kerala, the loss can be as high as 90 percent during heavy infection (Rajan and Agnihotri, 1989). Rain shelter cultivation of ginger can be considered as an alternative to decrease disease intensity and to increase the rhizome yield and quality which needs to be investigated. Early harvesting of the rhizome at vegetable maturity stage (5-6 months after planting) helps the farmers to get higher price in the market. Physiochemical parameters of ginger at different maturity stage are not studied and need to be analyzed. The lack of notable post-harvest processing for ginger resulted in poor return to the farming community. Dry ginger continues to be the only primary product produced and marketed from Kerala resulting in cyclic price crash. Fresh ginger suffers from weight loss, shrinkage, sprouting and rotting during storage. Fresh ginger are perishable in nature and are spoiled due to improper handling, growth of spoilage micro organisms, wilting and sprouting, action of naturally occurring enzymes, chemical reactions and structural changes during storage. Low shelf life of fresh ginger and inadequate facility for their modern storage leads to distress sale. Value addition could be a viable alternative which will fetch remunerative price to growers. Value addition has great scope considering the present industrial scenario with the perspective of increasing the acceptability, demand and value of spices and developing new markets. Fiber, volatile oil content and pungency level are the important criteria in assessing suitability of ginger rhizomes for particular processing purposes. Elite varieties satisfying the requirements for specific end products are the need of the hour to capitalize on the processing front. Chemoprofiling and identification of new flavoring compounds helps in bioprospecting of ginger.

Development of varieties and technologies to improve the yield and quality of products needs focusing now a days. A DBT funded project operated in the Department of Plantation Crops and Spices since 2006, resulted in the development of a good number of ginger somaclones which are being maintained in the department. From this genetic stock, few somaclones were selected for systematic evaluation on large scale for detecting their yield and quality. The proposed project envisages screening selected ginger genotypes for yield and quality, studying the performance of selected genotypes under different growing conditions and different maturity stages and identification of genotypes suitable for different value added products.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

The investigation on "Screening ginger (*Zingiber officinale* Rosc.) genotypes under different growing conditions and for value addition" focus on screening ten somaclones of ginger along with three check varieties for variability in yield and suitability for value addition and four somaclones along with one check variety for variability in growth characters, yield, quality attributes and resistance/tolerance to major diseases and pest under different growing conditions and at different maturity stages. The literature related to these aspects in crop plants with special reference to ginger are dealt in this chapter.

2.1 CLONAL VARIATION IN GINGER

Ginger is a rhizome propagated crop. Cultivar diversity abounds in India and China, which represents the centre of origin of this species, unlike Simmonds (1979) observed in many other crops. Geographical spread of ginger clones coupled with mutation and selection are considered to be responsible for the cultivar diversity (Ravindran *et al.*, 1994). Somaclonal variation, as a method to create variability has been effectively utilized for improving yield in a variety of zingiberaceous crops including ginger (Paul 2006; Shylaja *et al.* 2003; Kurian 2010), turmeric (Roopadarsini and Gayatri 2012), kacholam (Geetha *et al.* 1997; Joseph 1997), small cardamom (Reghunath 1989; Lukose *et al.* 1993; Reghunath and Priyadarshan 1993; Kuruvila *et al.* 2005) and large cardamom (Rao *et al.* 2003). According to Borthakur (1992) and Yadav *et al.,* 2004, the difference in quality parameters is due to the inherent characters of the varieties. Inter-varietal differences in growth pattern of ginger were also observed by Angom (2000), Tiwari (2003) and Jyotsna *et al.* (2012).

2.1.1 Morphological Characters

Nybe (1978) studied morphological variations in twenty five types of ginger and found that all the morphological characters varied among types except for leaf breadth, leaf area index and number of primary fingers. Height of plant, number of leaves per tiller, number of roots per plant was highest in Valluvanad and number of primary fingers per plant and secondary fingers per plant were more in Wayanad local and Bajpai respectively.

Mohanty *et al.* (1981) evaluated twenty eight cultivars of ginger for variations morphological characters and revealed that there was significant difference among them in, number of tillers, number of leaves, plant height, leaf length, weight of straw, number of adventitious roots, number of root tubers, total number of rhizome fingers, girth of secondary fingers and rhizome yield. Nybe *et al.* (1980) studied twenty eight cultivars for fresh and dry rhizome yield and reported significant differences among them. Fresh rhizome yield was highest in the case of cv. Nadia, followed by cultivar Moran, Bajapi and Narasapattam. Cultivar Nadia also gave the highest yield for dry ginger.

Singh *et al.* (2000) noticed the highest plant height (87.67 cm) in ginger cv. Nadia and the lowest plant height (70.84 cm) in cv. Karakal under Himachal Pradesh conditions.

According to Kale (2001) and Kuruber (2003), the maximum plant height was recorded in ginger genotype Humanabad under Ghataprabha Left Bank Command (GLBC) area of Belgaum district of Karnataka.

Anusuya (2004) observed the maximum plant height (66.06 cm) in Salem varieties, which were on par with Alleppey (63.06 cm) and PTS- 24 (62.66 cm) varieties of turmeric. The minimum plant height was observed in PCT-8 (36.73 cm), PCT-13 (37.86 cm) followed by black turmeric (43.26 cm) among 21 cultivars of turmeric grown under irrigated condition of Northern Karnataka.

Dhatt *et al.* (2008) reported the highest plant height (113.61 cm) in genotype 'PH 3' which was *on par* with 'PH 5' (105.57 cm) in turmeric.

Jadhav *et al.* (2009) recorded the maximum plant height (95.91 cm) was recorded in the variety Waigon whereas, minimum plant height (78.43 cm) in the variety Salem cultivated in Maharashtra.

Iwo *et al.* (2011) observed that the highest plant height (42.7 cm) and (24.27cm) in varieties ST Vincent in Umidike and Rio-de-Janerio in Calabar whereas, the lowest plant height in the varieties Rio-de Janerio (36.4cm) and HPL (12.74 cm) in Umudike and Calabar places.

Rajalakshmi and Umajyothi (2014) assessed eight varieties of ginger and noticed significant differences among the varieties. The maximum plant height (50.60 cm) was recorded in the cultivar Suprabha followed by Chintapalli local (49.87 cm), ACC-117 (48.60 cm), whereas, the lowest plant height (32.73 cm) was recorded in Varada under high altitude area of Andhra Pradesh.

Singh *et al.* (2000) reported the highest number of tillers (9.93) per plant in cv. Nadia and the lowest number of tillers (5.36) per plant were recorded in cv. Karakal in ginger under Himachal Pradesh condition.

According to Dhatt *et al.* (2008), the highest number of tillers per plant the maximum value was recorded in 'PH 3' (4.88) evaluated in Punjab Agricultural University, Ludhiana in turmeric.

Deshmukh *et al.* (2009) claimed the highest number of tillers per plant in turmeric cv. Krishna (5.99) under Nagpur conditions.

Among ginger varieties the highest number of tillers were recorded in variety UGI (6.1) and in UGII (13.10) at Umidike and Calbar region. While, the lowest number of tillers were recorded in the variety Rio-de- Janerio (4.8) and HPL (8.67) in Umudike and Calbar condition under humid agro-Ecology of Nigeria as reported by Iwo *et al.* (2011).

Virendra *et al.* (2015) screened seven turmeric genotypes and observed significant differences among the genotypes. The highest number of tillers per plant (5.39) was recorded in the variety Suroma followed by Roma (4.67), whereas, the local variety has registered the lowest number of tillers (3.70) under southern parts of Rajasthan.

Singh *et al.* (2000) reported the highest number of leaves per plant (20.03) in cv. Deomali and the lowest number of leaves per plant (15.82) were recorded in cv. Karakal in ginger under Himachal Pradesh condition.

Dhatt *et al.* (2008) observed that 'PH 3' variety of turmeric possessed the maximum leaves per plant (25.90) followed by 'Narendra Sonia' (23.22) and 'PH 4' (23.50).

Deshmukh *et al.* (2009) claimed that among eight turmeric cultivars evaluated the variety Krishna recorded the maximum number of leaves per clump (12.55) and more number of leaves per tiller (5.99) under Nagpur conditions.

According to Iwo *et al.* (2011), among seven ginger genotypes cultivated in Umudike and Calabar regions, the highest number of leaves (19.6) were recorded in the variety Rio-de-Janeiro and HPL (6.87), while the lowest number of leaves were recorded in the variety Wynad local (13.1) and Rio-de-Janeiro (4.43) in Umudike and Calabar conditions under Humid agro-Ecology of Nigeria.

Muhammad *et al.* (2012) reported that among three turmeric cultivars the maximum number of leaves was recorded in Krishna at three different locations i.e Gomal University (13.74), farmer field (12.97) and Ratta kulachi (13.73) and lowest number of leaves were observed in Duggirala variety.

Sangeetha and Subramanian (2015) found that there was significant variation with respect to number of leaves among different ginger genotypes and ZO 26 produced maximum number of leaves (148.56) at 150 DAP.

Goudar *et al.* (2017) reported significantly variation among number of leaves per clump among the genotype and Humnabad Local (257.60) on par with Bidar-2 (242.93) and Rajatha (226.90), while genotype Himachal recorded lowest number of leaves (118.70).The number of leaves per clump is important, as it is a source of carbohydrate production which is utilized for buildup of new cells. This leads to better growth, absorption of nutrients and ultimately increase in production of fresh and dry weight of plants.

Jagadish (2000) revealed maximum leaf area in turmeric variety Bangalore local (38.38 cm2) which was on par with varieties, Suvarna (38.14 cm^2), Bidar-1 (28.61 cm^2) and Cuddapah (28.39 cm^2) followed by Rajapuri (25.38 cm^2), Sangli (24.69 cm^2) and BSR-1 (23.81 cm^2), while the minimum leaf area per plant (12.78 cm2) was recorded in variety D. K. Local under rain fed condition of hill zone.

Anusuya (2004) reported the maximum leaf area in mango ginger (53.40 cm2) followed by Cuddapah (47.36 cm^2) and Alleppey (46.20 cm^2) varieties of turmeric, while the minimum leaf area was observed in Black turmeric (24.66 cm^2) among 21 cultivars of turmeric grown evaluated in Northern Karnataka.

Hrideek *et al.* (2006) reported the highest leaf length (44.27 cm) and breadth (40.83 cm) in IISR Prabha, followed by IISR Kedaram (40.87 length and 40.25 breadth) in turmeric grown at higher elevation of Western Ghats.

Iwo *et al.* (2011) investigated seven ginger genotypes cultivated under humid agro-ecology of Nigeria. They reported that the highest leaf area (52.6 cm^2) in the variety Wynad local whereas, the lowest leaf area (39.6 cm^2) was recorded in the variety Rio-de Janeiro.

Siddalingayya *et al.* (2014) screened 16 varieties of turmeric for commercial production in southern dry zone of Karnataka and reported the maximum leaf area per plant in variety CLT-325 (55.80 cm^2) which was at par with variety Cuddapah (55.83 cm^2), whereas, the minimum leaf area (39.97 cm^2) was recorded in variety Krishna.

2.1.2 Rhizome Characters and Yield

According to Nybe *et al* (1979 b), the number of primary rhizomes and intermodal length of rhizomes was the most variable characters.

Ramachandran (1982) and Ramachandran and Nair (1992) tested successful production of stable tetraploid lines in cvs. Maran and Mananthody. The polyploids were more vigorous than the diploids and flowered during the second year of induction. The stable tetraploid lines had larger, plumpy rhizomes and high yield (198.7 g/ plant). However, the essential oil content was lower (2.3%) than the original diploid cultivar. There was a considerable increase in pollen fertility in tetraploids.

Sreekumar *et al.* (1982) reported that Rio-de-Janeiro and Kuruppumpadi were the best yielders.

High heritability coupled with high genetic advance for rhizome yield per plant in ginger was also reported by Maity *et al.* (1989) and Pandey and Dobhal (1993).

Rai *et al.* (1999) reported the highest fresh rhizome yield (462.6 g/ plant) in cv. 'Gorubathaney' and the lowest (234.5 g/plant) in 'Suprabha'.

Ram and Sheo (1999) screened twenty-one indigenous and exotic genotypes of ginger (*Zingiber officinale*) for three consecutive years. Yield was positively and significantly correlated with tillers/clump (r=0.83), internodal distance of rhizome (r=0.51) and plant height (r=0.50) and was negatively correlated with fibre content (r=-0.53). Karakai, Chekeralla, Rio-de-Janeiro, Thingpuri and Khonsa Local had high rhizome curing percentage (19.1-20.4%). The highest fibre content (7.6%) was recorded in Khasi Local and lowest in

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Nadia. However, Tura yielded highest (266.9 q/ha) followed by Poona (250.4 q/ha) and Basar Local (248.8 q/ha).

Singh *et al.* (1999) evaluated eighteen ginger cultivars for growth, yield and quality in Nagaland. Thinglaidum, Nadia and Khasi Local were tallest and had most tillers/plant. They also had the highest rhizome yields (more than 30 tonnes/ha). The lowest rhizome yield was recorded in Tura and HP 666 (less than 20 tonnes/ha). Thinglaidum, Nadia and Rio-de-Janeiro had the best fibre and oil contents.

Kuruber (2003) observed significant variations among the ginger genotypes for number of days taken from planting to harvesting, which ranged between 200-241 days. The variety Maran recorded early maturity (200 days) and Kundapur recorded late maturity (241 days) under northern dry zone of Dharwad conditions of Karnataka.

Sasikumar *et al.* (2003) evaluated 15 bold rhizome accessions selected from ginger germplasm for yield and quality in multilocation trials. Based on the overall superior performance, the accessions 35 and 107 were selected, multiplied and released under the name IISR Rejatha and IISR Mahima, respectively.

High quality rhizome (grade I) should have 22% dry matter, 5% oleoresin, and 8% or less crude fiber (Anon., 2004).

According to Hrideek *et al.* (2006), the turmeric variety Kedaram took the minimum (250 days) for maturity followed by Prathibha (260 days) at higher elevation of Western Ghats.

Singh and Prasad (2006) assessed 16 turmeric cultivars and reported that the cultivars ACC-657 and ACC-585 required a longer period to maturity (262 and 238 days, respectively).

Chongtham *et al.* (2013) reported that the length of primary fingers varied from 3.00 cm to 3.53 cm while the length of secondary fingers varied from 2.53

cm to 3.73 cm. The diameter of primary fingers ranged from 1.71 cm to 2.28 cm and that of secondary fingers ranged from 1.65 cm to 1.95 cm.

Sangeetha and Subramanian (2015) reported that the characters of primary rhizome as well as secondary rhizomes registered higher values in the genotypes of ZO 26 and suggested that this might be due to the fact that the secondary rhizomes being farthest in the accumulation zone, received lesser quantities of photosynthates and probably with lesser quantity which could not be accumulated in the mother and primary rhizome components, getting partitioned to the secondary rhizomes. Similar result was reported by Vijaya (2003) and Arunkumar (2003).

The variety Bhaisey took minimum time (58.7 days) for sprouting followed by Gorubothan (59.9 days), Nadia (61.1 days), whereas, the variety Manipur local took maximum time (61.8 days) for sprouting in ginger under rain fed condition of Manipur as reported by Jyotsna *et al.* (2012).

Primary and secondary rhizomes numbers are one of the major yield contributing characters in ginger. Among the ginger genotypes evaluated for higher yield and quality attributes, suitable for high rainfall zone of Tamil Nadu, the number of primary rhizomes ranged from 5.12 to 7.98 (Balakumbahan and Joshua, 2017).

Goudar *et al.* (2017) reported that on evaluation on genotypes under Karnataka condition, the high yielding genotypes recorded higher values for growth parameters and yield attributing characters *viz.,* number, length and girth of primary rhizomes and secondary rhizome which also contributed to higher yield. Percentage of dry ginger recovery ranged from 18.47 to 26.32.

The higher fresh rhizome yield in the genotypes Humnabad Local and Rajatha is attributed to the growth parameters like plant height, number of leaves per plant and number of tillers per plant (Goudar *et al.*, 2017).

According to Surendrababu *et al.* (2017), the yield of fresh rhizome is the inherent capacity of the variety to put forth better growth in terms of leaf area and no of leaves, no of tillers, plant height and leaf area index of the plant and better growth and production of yield attributes like weight of primary and secondary rhizomes, no of finger rhizomes, no of primary and secondary rhizomes. It can be concluded that the yield of a variety is dependent on vigour of the plant and other plant characters.

2.1.3 Quality Parameters

Crude fiber content of dried ginger ranged from 4.8 to 9% (Natarajan *et al.*, 1972).

Jogi *et al.* (1972) studied 14 cultivars and reported that the fibre content ranged from 4.62 (cultivar Poona) to 6.98 per cent (cultivar Narasapattam. Cultivar Karakkal was lowest in dry recovery followed by cultivar Wayanad local and Rio-de-Janeiro. Cultivar Rio-de-Janeiro had the highest oleoresin, whereas cultivar Karakkal had the highest oil. Crude fiber was least in the cultivars Nadia and China.

In Rio-de-Janeiro variety, yield of green ginger, oil and oleoresin content were highest at 7 months, whereas dry ginger recovery and starch content were highest at 8 months maturity (Jayachandran *et al.*, 1980).

In an evaluation on the volatile and non volatile extract for ginger from various countries, volatile oil and non volatile extract recorded for Indian ginger was 2.2 and 4.25 per cent respectively. With respect to Sierra Leone and Jamaican ginger, volatile oil and non volatile extract were 1.6, 7.2 and 1.0, 4.4 respectively (Akhila and Tewari 1984).

Baranowski (1986) studied the cv. Hawaii for 34 weeks and recorded the growth- related changes of the rhizome. The solid content of the rhizome increased throughout the season, but there was decline in the acetone extractable oleoresin content of dried ginger, the oleoresin content on fresh weight basis was roughly constant. The (6)-gingerol content of ginger generally increased with the age of the rhizome on a fresh weight basis. On a dry weight basis, gingerol generally exhibited a linear increase with maturity up to 24 weeks, followed by a steady decline through the rest of the period.

Haq *et al.* (1986) evaluated the composition of ginger from Bangladesh and found that rhizome contains essential oil (4%), ash (6.5%), proteins (12.3%), water-soluble proteins (2.3%), starch (45.25%), fat (4.5%) including free fatty acids, sterols (0.53%), cold alcoholic extract as oleoresin (7.3%), water solubles (10.5%), crude fiber (10.3%).and minerals (in g/100 g): Ca (0.025), Na (0.025), K(0.035), Fe (0.007), P(0.075), Mg (0.048), Cl (1.5ppm) and F(5.0ppm).

The content of the active principle as well as the yields of ginger oleoresin containing gingerols and other bioactive compounds are not uniform and can vary significantly between cultivars and regions in which ginger is growing (Ratnambal *et al.* 1987; Kizhakkayil and Sasikumar 2009; Sanwal *et al.* 2010).

Characterization of ginger for the major biochemical constituents viz. oleoresin, essential oil and crude fibre levels has lead to identification of cultivars rich in one or other of these constituents. Oleoresin content of ginger varied from 3 to 11% depending on the genotype, solvent extraction condition, state of rhizome, place of origin and harvest season (Ratnambal *et al.*, 1987; Vernin and Parkanyl, 2005).

Three pungent compounds of gingerols are reported and quantified in ginger (Chen *et al.*, 1986). Among the gingerols and shogaols, 6-gingerol was the most abundant pungent compound reported (Chen *et al.*, 1986; Bartley, 1995).

HPLC analysis of ginger accessions GC/MS method is not suitable for the analysis of pungency, because the high temperature will convert gingerol to shogaol (Harvey, 1981; Chen *et al.*, 1986).

Both the volatile and non-volatile compounds of ginger are credited with medicinal properties besides imparting pungency and aroma to ginger as a spice.

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Essential oil content of ginger varied from 0.2 to 3%, depending on the origin and state of rhizome (van Beek *et al.*, 1987; Ekundayo *et al.*, 1988).

Mohanty and Panda (1991) investigated induced mutation in ginger. Mutations were artificially induced in 5 ginger cultivars by employing one physical and three chemical mutagens. Twenty selected MV3 generation mutants, along with the parental material, were compared in a 3-year yield evaluation. The highest yield was given by V1K1-3 (22.08 t/ha) followed by Suprabha (16.6 t/ha) and V2E5-2 (15.4 t/ha), in contrast to the parental cultivar UP (5.93 t/ha). The performance of 6 highest yielding lines, evaluated in a four year trial, confirmed the superiority of V1K1-3 (20.3 t/ha). Based on uniformly high yield, dry recovery, oleoresin and essential oil percentages, V1K1-3 mutant was recommended for release under the name Suravi during 1991.

Saika and Shadeque (1992) studied twenty exotic and indigenous cultivars and reported that, Moran, Jorhat Hard, Thinlaidum and Wynad had high fiber contents (7-8%). Although not suitable for raw spices, Moran and Jorhat Hard were suitable for the extraction of oleoresins and volatile oils.

Gingerols and shogaols are pungency stimulating non-volatile compounds found in ginger Pungency of the ginger gradually decreases when the amount of gingerol decreases and shoagaol increases (Zachariah *et al.*, 1993).

Goyal and Korla (1997) recorded fresh yield, dry weight, essential oil, oleoresin and crude fibre contents of four ginger genotypes at different stages of rhizome development. In all genotypes, both fresh and dry weights of rhizomes increased steadily up to 225 days after planting. In fresh rhizomes, essential oil content peaked 210 days after planting, but essential oil as a percentage of dry weight decreased continuously throughout rhizome development. Oleoresin content on a dry weight basis declined until 210 days after planting, beyond which the contents increased in one genotype and remained unchanged in others. After an initial increase, crude fibre content on a dry weight basis decreased gradually until 210 days and then increased further with rhizome age. Except for the initial stage of rhizome development, the fresh rhizomes had the lowest level of crude fibre at 210 or 195 days in different genotypes. Harvesting between 225-240 days after planting is recommended to maximize the fresh yield, oleoresin content and recovery of dry ginger.

John and Ferreira (1997) screened five ginger selections under tropical conditions at Levubu area in South Africa and reported that there were significant differences ($P < 0.05$) in mass of fresh rhizomes, moisture and crude fibre content but not in the oleoresin and ginger oil content among the selections. G13 ranked first in respect of the mass of fresh rhizomes with high moisture content but lowest in the crude fibre content on wet basis. The selection G9 with a high crude fibre content of 6.8% on dry basis recorded the best results in terms of oleoresin (3.06%) and oil (0.52%) contents, however the dry ginger recovery was highest with G10 (27.5%). Thus, among the five selections studied G13 (Brazilian) gave better results for the early harvesting ginger industry (confectionery). For the drying and extraction

Nakasone *et al.* (1999) opine that gingerol contents of the tetraploid strains were much higher than the diploid counterparts and they also showed that differences in pungency intensity between the diploids and the tetraploids, as evaluated by sensory test, were consistent with gingerol contents.

Datta *et al.* (2003) investigated quality of 12 ginger cultivars (Tanda, Rajgarh, Jughijan, Tura, Mazulay, Suprabha, Taffingiva, Suravi, Uttar Pradesh, Gorubathan, Bhoinse and local cultivar) grown in the subtropical humid region (Mondouri) of West Bengal, India. The dry recovery percentage was highest in Tura (26.77%) and lowest in Bhoinse (15.84%). Greater recovery (≥20%) was also recorded for Suravi (23.45%), Suprabha (20.60%), Uttar Pradesh (20.48%) and Gorubathan (20.30%). Suravi was superior in terms of oleoresin (10.3%) and essential oil (2.07%) contents.

Shankar (2003) screened seven induced variants along with three check varieties to exploit induced variability in ginger. Among the induced variants, autotetraploids Z-0-78 recorded the maximum driage (22.56%) whereas highest oil content was recorded in Z-0-86 (2.07%). Z-0-86 recorded the lowest fibre content (2.70%). With respect to oil yield per hectare, Rio-de-Janeiro registered the maximum value of 76.02 kg ha-1 followed by autotetraploid Z-0-86 (55.50 kg ha-1). The colour of oil varied from light yellow to dark yellow. Sensory evaluation indicated that Rio-de-Janeiro had good sensory score ("++++") and the least preferred was Z-0-92 and Z-0-95 ("+"). With respect to oleoresin extracted with acetone and ethyl acetate, Z-0-86 recorded maximum content (9.16% and 7.74% respectively), whereas Rio-de-Janeiro gave the maximum oleoresin yield per hectare (280.15 kg ha-1 and 288.66 kg ha-1 respectively) followed by Z-0-86 (246.28 kg ha-1 and 207.97 kg ha-1 respectively). The colour of oleoresin extracted using acetone and ethyl acetate varied from pale brown to dark brown. Sensory evaluation of oleoresin indicated that Rio-de-Janeiro had most pleasing aroma with acetone and ethyl acetate as solvents. When extraction efficiency of solvents was compared, acetone was found to extract more oleoresin content (5.91%) than ethyl acetate (3.86%).

Jolad *et al.* (2005) and Kizhakkayil and Sasikumar (2012) observed meager levels of shogaol in the accessions of ginger in HPLC analysis.

Wohlmuth *et al.* (2006) reported the absence of shogaol in the fresh ginger from Australia and supported the hypothesis that shogaols are not native constituents of fresh ginger rhizomes, but formed from gingerols by dehydration as a result of heat or acidic or alkaline con-dition, but in the present study shogaol was found with gingerol, as a naturally occurring constituent in most of the accessions.

The aroma of ginger is pleasant and spicy and its flavor penetrating, slightly biting due to presence of antiseptic or pungent compounds, which make it indispensable in the manufacture of a number of food products like ginger bread, confectionary, ginger ale, curry powders, certain curried meats, table sauces, in pickling and the manufacture of certain soft drinks like cordials, ginger cocktail, carbonated drinks, bitters, etc. Ginger is also used for the manufacture of ginger oil, oleoresin, essences, tinctures etc. (Pruthi 2006).

Jiang *et al.* (2006) reported that, in order to find out the variability in pungent components among germplasm collections of ginger, HPLC is a better option for the analysis.

Ratio of 6-gingerol to 6-shogaol decides the quality of the ginger (Schwertner and Rios, 2007).

The main volatile compounds are mono- and sesqui-terpenes, camphene, phellandrene, curcumene, cineole, geranyl acetate, terphineol, terpenes, borneol, geraniol, limonene, linalool, zingiberene, sesqui-phellandrene, bisabolene and farnesene. Many of these compounds are credited with curative properties (Chen *et al.*, 2007, Shukla and Singh, 2007, El-Baroty *et al.*, 2010 and Hsu *et al.*, 2010).

Flavour and pfdungency of ginger is valued by the quantum of oleoresin present in the rhizomes Menon *et al.* (2007).

Fiber content is one of the most important criteria for assessing the suitability of ginger rhizome for its value addition like ginger paste, salted ginger, ginger powder etc. (Kizhakkayil and Sasikumar 2009).

Among the gingerols and shogaols identified in ginger genotypes, 6-gingerol was the predominant one in all the ginger accessions except the exotic ginger, 'Oman', in which 8-shogaol was the predominat one. Highest level of 6-gingerol was recorded in the cultivar, 'Angamali' (3.11%) and the least in the exotic ginger, 'Oman' (0.36%). Even though 6-shogaol was present in all the samples, its con-centration was relatively low when compared with 6-gingerol. 8-gingerol, 10-gingerol, 10-shogaol were also present in many of the ginger accessions (Kizhakkayil and Sasikumar 2012).

Karthik *et al.*, (2017) reported that the highest essential oil percentage was recorded with T8-Acc-701 (1.71 %) followed by T5-Acc-219 (1.66 %), T16-Gorubathan (Control.) (1.59 %) and was lowest with T10-Acc-239 (0.92 %). The oleoresin percentage was recorded maximum with T4-Acc-65 (9.25%) followed by T2-Karthika (8.73 %) and the lowest with T13-Acc-278 (3.30%).

Ajay *et al.* (2013) reported the biochemical composition of two ginger varieties from Nigeria. Contents of crude fibre (21.90, 8.30), fat (17.11, 9.89), carbohydrate (39.70, 58.21), crude protein (12.05, 11.65), ash (4.95, 7.45) and moisture (3.95, 4.63) were reported in the two types respectively.

In a study on the effect of dates of planting on growth, yield and quality of ginger, Yadav *et al.* (2014) reported that April 15th planting showed better oil content. Among spacings, the spacing of 35 cm × 25 cm gave highest dry recovery. The closer spacing of 15 cm × 25 cm recorded higher harvest index. It was observed that spacing had no significant effect on quality attributes viz., oil and crude fibre content. The treatment combination of 15^{th} April planting and 35 cm × 25 cm spacing exhibited higher dry recovery. The treatment combination of 15th April planting and 15 cm × 25 cm spacing showed maximum harvest index.

2.1.4 Pest and Disease Incidence

Pests

Nybe and Nair (1979 a) reported that among 25 cultivar of ginger screened for stem borer infestation, though not significant, Valluvanad (43.40%) was the most affected one followed by Jorhat (40.20%), Nadia (38.80%), China (37.60%), Assam (36.50%) and Vengara (36.30%). It was also noticed that the types Rio-de-Janeiro (21.30%), Wynad Kunnamangalam (24.30%), Arippa (24.70%) and Thodupuzha (25.80%) were comparatively less susceptible than other types.

Koya *et al.* (1986) investigated the yield loss caused by stem borer (*Conogethes punctiferalis*) in Kerala and results indicated that when 50 per cent pseudostems in a plant are affected, there was significant reduction of 38 g of yield per plant.

According to Nybe (2001), when 23 to 24 per cent of pseudostems of a plant are infested by the pest, about 25 per cent yield loss occur and the pest caused 40 per cent yield loss in Kottayam and Idukki districts of Kerala.

Shankar (2003) studied seven variants along with three check varieties and found that Rio-de-Janeiro showed the least percentage of shoot borer attacked tillers (19.99%) whereas Z-0-97 had the least percentage of attacked plants (29.37%).

Devasahayam *et al.* (2010) evaluated 492 accessions of ginger in the field against the shoot borer for four consecutive years. All the accessions were susceptible to the pest attack. None of the accessions was rated as resistant, whereas, 49, 251, 130 and 62 accessions were rated moderately susceptible, susceptible and highly susceptible respectively. Among the popular cultivars, Jorhat, Rio-de-Janeiro, Thingpuri and Burdwan were rated as moderately resistant and among the high yielding varieties released by IISR, Calicut, Rejatha was moderately susceptible; Mahima and Varada were susceptible.

Disease

Clones 'Maran' 'Suprabha' and 'Himachal' have been reported to show field tolerance to ginger rot (*Pythium aphanidermatum*) (Indrasenan and Paily, 1974; Setty *et al.*, 1995).

Nybe and Nair (1979 a) screened 25 ginger cultivars for rhizome rot incidence. Among them, Rio-de-Janeiro showed maximum susceptibility (27.50%) to soft rot disease followed by Tafingiya (26.40%), Taiwan (23.40%) and Himachal Pradesh (16.30%). The infection was very mild in the types Maran (3.20%), Vengara (3.40%), Wynad local (16.30%), Wynad Mananthody (3.60%) and Kuruppampady (3.60%). The incidence was medium in Bajpai (5.32%) and Nadia (7.50%)

Shankar (2003) tested seven variants along with three check varieties and found that Himachal Pradesh showed the least susceptibility to soft rot (20.28%).

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Bacterial wilt (*Ralstonia. solanacearum*), soft rot (*Pythium* spp.) and shoot borer (*Conogethes punctiferalis*) are three major pests of ginger. No stable bacterial wilt resistant ginger cultivar is known to exist. Consistent with this, 600 accessions screened for bacterial wilt tolerance using soil inoculation method were found susceptible (Kumar and Hayward, 2005).

Shylaja *et al.* (2010) reported that the ginger clone 'Athira' is relatively more tolerant to bacterial wilt and soft rot than its mother clone 'Maran'.

2.2 SOMACLONAL VARIATIONS

Ginger

Samsudeen (1996) investigated variability in ginger somaclones and found variability among somaclones in yield and yield attributes which resulted in identification of few promising high yielding lines with tolerance to rhizome rot.

Smith and Hamill (1996) reported that adventious bud regenerants of ginger cultivar Queensland were more vigorous with more no of tillers /plant and lengthy pseudostem than conventionally propagated (CP) plants.

Pandey *et al.* (1997) opined that conventially propagated plants of ginger cultivar Khin yai produced higher rhizome yield than adventitious bud regenerants. But rhizome of adventitious bud regenerants exhibited more branching indicating their yield potential.

According to Freitz *et al.* (2003) there was increase in tiller number, fresh and dry mass of shoots and roots in adventitious bud regenerants but rhizome yield and pseudostem length were more in control plants. Somaclones produced numerous small rhizomes with more number of fleshy roots and tuberous structures at the tips.

In-vitro regenerated ginger plantlets performed better than the conventional planting materials and maximum yield/plant (356 g) was recorded

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from planting materials derived from *in-vitro* regenerated plantlets harvested from field (Sit and Malay, 2007).

Yang *et al.* (2009) also opined that tissue cultures plantlets had the advantages of rapid growth, strong growth vigor, disease resistance, strong adverse resistance. Its tubers are of bright yellow color, uniform size, heavy peppery, high quality, high yield with above 5000 kg/667 m^2.

Induction of somaclonal variation in two polyploids (Z-0-78 and Z-0-86) and a diploid cultivar Himachal Pradesh was tried by Kurian (2010). Evaluation of 289 somaclones (generated through indirect organogenesis and embryogenesis) indicated that somaclones were less tall with more number of tillers and higher mean yield when compared to control cultivars raised through bud culture. Ten per cent of somaclones produced rhizome yield more than 300g and the percentage yield increase over the control cultivars ranged from 92-148.

Resmi and Shylaja (2012) screened ginger somaclones for three consecutive years and revealed that somaclones were superior to conventionally propagated plants for various growth, yield and quality parameters. Twenty nine per cent somaclones were found superior to conventionally propagated plants in characters like height of pseudostem, number of tillers/plant, number of leaves/tiller and leaf area. For rhizome characters, 30% clones were found superior to conventionally propagated plants. Eighteen per cent somaclones exhibited superiority in yield over conventionally propagated plants giving a yield increase of 13%.

Black pepper

Sanchu (2000) reported variability in black pepper cultivar Cheriyakaniyakkadan derived through indirect organogenesis for morphological, yield and quality parameters. Variability was observed in leaf area, number of lateral branches, number of spikes per branch, spike length, number of berries per spike and recovery of essential oil and piperine.

3

Cardamom

In a yield performance evaluation of tissue-cultured cardamom (*Elettaria cardamomum*) selections by Chandrappa *et al.* (1996), out of five selections, one selection had higher yields than control varieties *i. e.,* Mudigere 1 and Mudigere 2, while the other lines had yields similar to the controls.

Sudharshan *et al.* (1997) evaluated plants regenerated by tissue culture from 8 high-yielding clones of cardamom (*Elettaria cardamomum*) with open pollinated progenies of these clones in field trials at 56 locations in Karnataka during 1988-1989. Clonal populations varied in the type of panicle, capsule shape and size and sterility. Overall variability in tissue-cultured plants was 4.5% compared to 3.0% in open pollinated seedling progeny.

Kuruvilla *et al.* (2005) compared yield performance of tissue derived plants and an open pollinated seedling of cardamom. Somaclones were found superior to open pollinated seedlings in growth attributes such as number of tillers, bearing tillers, panicles per clump and yield. Irrespective of the seasons and location, 14 somaclones were identified with a yield potential of more than 750kg ha-1 under moderate management.

Large cardamom

A comparative study was conducted by Rao *et al.* (2003), on growth and yield of adventitious bud regenerants and open pollinated seedlings of large cardamom. An increase of 1.5 times in yield contributing characters such as number of total tillers / clump, productive tillers/ clump, spike/clump and capsules/ spike and twenty times increment in yield were recorded in the somaclones as compared to open pollinated seedlings.

Vanilla

Madhusoodanan *et al.* (2005) evaluated the performance of vanilla plants raised from tissue culture plantlets and vegetative cuttings on large-scale in planters' field covering a total area of 111 ha in Kerala, Karnataka and Tamilnadu. Observations on growth and yield attributes revealed that performance of tissue culture plants is on par with that of conventional plants raised from vegetative cuttings of comparable length. It is also reported that if good management practices are adopted, tissue culture plants perform better at the full bearing stage of the plant. This proves that tissue culture plants of vanilla can be popularized as a cost effective and faster source of planting materials compared to conventional vegetative cuttings.

Kacholam

Geetha *et al.* (1997) compared field performance of adventitious bud regenerants of *Kaempferia galanga* and *K. rotunda* for three seasons along with conventionally propagated plants. Somaclones were inferior in morphological characters and yield for first two seasons as compared to control plants but were on par with control plants in the third season

2.2.1 Somaclonal variations morphological parameters

The primary advantages with greenhouses are that any crop can be grown in any season of the year depending on the market demand, excellent quality of the produce, disease free produce etc.

Surendrababu *et al.* (2017) studied performance of ginger varieties under shade net condition and reported that the variety Suprabha recorded the highest plant height (89.83 cm) followed by Himachal (84.63 cm), Pundibari (82.56 cm) and Jalsingapara local (82.06 cm) and was *on par* with each other and the lowest plant height (72.56 cm) was recorded in the variety Maran. This might be due to genetic constitution of the varieties which were influenced by controlled climate under shade net condition because of low light intensity. Similar result was reported by Bhuiyan *et. al.* (2012).

The variety Suprabha recorded the highest number of tillers per plant (28.56) followed by varieties Hımachal (24.33) which were *on par* with each other and the lowest number of tillers per plant (13.46) was recorded in the variety Nadia under shade net condition (Surendrababu *et al.*, 2017). This might be due to genetic constitution of the varieties and genotypic potential and availability of nutrients in the soil, which were influenced by low light intensity and high relative humidity condition under shade net situation (Rajalakshmi and Umajyothi, 2014).

According to Surendrababu *et al.* (2017), the variety Suprabha recorded highest leaf area per plant (32.47 cm^2) and the lowest leaf area per plant (22.88 cm^2) in the variety Maran under shade net condition. It might be due to the differences in leaf length and width which was influenced by genetic makeup of the varieties and also due to environmental condition in the shade net. The ginger requires a day temperature of 28-35°c and high relative humidity throughout the crop period for increased leaf area in ginger (Shetty *et al.,* 2015).

Nkansah *et al.* (2017) reported a high yield difference between the greenhouse varieties and the open field planting of chilli, ranging from 50%-150% respectively. Zakaria (2003) revealed that the fully controlled greenhouse increased the fresh yield of sweet pepper by 176.8% and 228.5% as compared to partially controlled environment as this may be due to the favourable environmental condition. According to Ganesan and Subashini (1999), the performance of tomato grown inside the polygreenhouse was better than the crop grown in open condition and nearly 3½ times higher fruit yield was reported in poly-green house. Due to warm and humid weather inside, plant growth and yield attributing characters were also found to be higher inside the greenhouse. The yield potential of greenhouse is about 1.5 times more than the open field (Patel *et al.*, 2003). Chauhan (1972) also reported similar results for Okra crop.

Parvej *et al.* (2010) reported that the microclimate variability inside the polyhouse favored the growth and development of tomato plant by increased plant height, number of branches plant^{-1}, rate of leaf area expansion and leaf area index over the plants grown in open field.

Ginger plants grown as an intercrop were significantly taller than those under open conditions (sole crop), when measured 200 DAP and had significantly lower number of functional leaves and tillers per clump. Interception of photosynthetically active radiation (PAR) by ginger was maximum at 110 DAP, both in open conditions (1.088 ly/min) and in the intercrop (0.788 ly/min). Percentage of PAR intercepted by ginger out of total PAR was lowest at 170 DAP in both open (74.4%) and under arecanut shade (56.41%). Mean duration of ginger crop grown in open conditions was 184.4 days, while it was 198.5 days when grown as intercrop. Per plant yield of ginger under arecanut plantation was significantly higher (154.5 g) when compared with open conditions (118.8 g/plant) (Hegde *et al.*, 2000).

Stomatal conductance and stomatal frequency decreased with increasing shade levels, and were highest in plants grown under open conditions. In contrast, stomatal resistance increased with increasing shade levels and was highest (77.68 m^2/s^1/mol) with 80% shading. Photosynthetic and transpiration rate decreased with increasing shade levels and were highest (7.76 µmol $CO_2/m^2/s^1$ and 2.27 mol $H_2O/m^2/s^1$, respectively) in plants grown under open conditions. LAI and DM yield were highest with 20% shading (8.18 and 25.32 g/plant, respectively) and decreased with higher shade levels (Sreekala and Jayachandran, 2001).

2.2.2 Somaclonal variations for quality

Ginger

Ramachandran and Nair (1992) reported that, tetraploid lines from cultivars Maran and Mananthody gave lower essential oil content (2.3%) than the original diploid cultivar.

According to Bhagyalakshmi *et al.* (1994), mericlones of ginger cultivar Wynad local were comparable to the CP plants in the composition of starch, ash, acetone extract and volatile extract.

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Zarate and Yeoman (1996) opined that accumulation of [6] gingerol and [6] shogaol (phenolic pungent principles of ginger) was much higher in culture systems of *Zingiber officinale* where morphological differentiation was apparent. Cultures grown on a callus-inducing medium also accumulated these metabolites but to a lesser extent. There is a positive relationship between product accumulation and morphological differentiation, although unorganized callus tissue also seems to possess the necessary biochemical machinery to produce and accumulate some phenolic pungent principles. In contrast to earlier studies with the intact plant, there was no positive correlation between the amount of [6] gingerol accumulated and the number of pigmented cells in either of the culture systems investigated.

The quality somaclones of Jamaican ginger were superior to the local ginger cultivar Kuruppapady in terms of oil and oleoresin recovery, as reported by Rao *et al.* (2000).

Smith *et al.* (2004) developed a tetraploid line named Buderim Gold, from Queensland a local cultivar. Tetraploid had compared the most favorably with 'Queensland' in terms of the aroma/ flavor profile and fibre content at early harvest, and had consistently good rhizome yield. The tetraploid had large rhizomes sections, resulting in a higher recovery of premium grade confectionery ginger and a more attractive fresh market product.

Paul (2006) compared somaclonal variation in two cultivars of ginger, Maran and Rio de Janeiro and found that the somaclones exhibited superiority over control plants in quality characters. Somaclones recorded higher dry recovery (19.73%) than conventionally propagated plants (16.02%). Of the two cultivars studied, higher driage was noticed in the clones of cultivar Maran (18.25%) than clones of cultivar Rio-de-Janeiro (15.62- 15.79%). In three clones of cultivar Maran viz. 488M, 110M and 970M, the driage recorded was very high registering driage values of 25, 22.56 and 22.50 per cent respectively. Recovery of essential oil varied between 1.00 to 2.50 per cent. Oil content was found high in somaclones of cultivar Rio-de-Janeiro (1.42 to 2.50%) than clones of cultivar Maran (1.00 to 2.25%). Oleoresin content ranged from 4.31 to 8.93 per cent in the somaclones evaluated. Higher recovery was noticed in clones of Rio-de-Janeiro (4.38 to 8.93%) than the clones of cultivar Maran (4.31 to 8.49%). Fibre content ranged from 1.96 to 6.86 per cent in the somaclones studied. Somaclones of cultivar Maran recorded low fibre content (1.96 to 5.24%) as compared to cultivar Rio-de-Janeiro (4.27 to 6.86%). Clones of cultivar Maran, M VI (1.96%) and 79 M (2.28%) showed the lowest crude fibre content.

Sanal *et al.* (2010) carried out an investigation to explore variability between 18 diploids and tetraploids genotypes for their gingerol content. The teraploid ginger type was derived from the respective diploid ginger by shoot tip culture. (6)-Gingerol was the major pungent phenolic compound in all samples, while (8)-gingerol and (10)-gingerol occurred in lower concentration. The total gingerol content of the tetraploid type was much higher than that of the respective diploid type and especially (10)-gingerol type.

According to Shylaja *et al.* (2010), two new ginger varieties developed at Kerala Agricultural University, from cv. Maran, exploiting somaclonal variation. Athira is a high-quality cultivar suitable for fresh and dry rhizome, has low crude fibre contents and high zingiberene contents. Karthika is a high-yielding clone that produces highly pungent rhizomes rich in gingerol, suitable for the extraction of oleoresin

Resmi and Shylaja (2012) claimed that somaclones were superior over conventiotially propagated plant in attributes like dry ginger recovery, percentage of essential oil, oleoresin and fibre content.

Turmeric

Roopadarshini and Gayatri (2012) assesed somaclonal variation in turmeric. Significantly high curcumin, oleoresin and volatile oil contents (%) were observed in somaclonal variants when compared to the normal regenerants and also control plants.

2.3. Physiological parameters under different growing conditions

The higher temperatures has more adverse influence on net photosynthesis of the crop than lower temperature leading to decreased production of photosynthetic activity above a certain temperature in bell pepper (Bhatt and Rao, 1993).

Pooja and Hakkim (2017) reported that, in tomato raised in naturally ventilated polyhouse and rainshelter, the temperature was found higher inside the polyhouse than the rainshelter throughout the crop period. The monthly average maximum and minimum temperature in the afternoon was higher compare to morning and evening inside both the structures. The rise in air temperature inside the polyhouse compared to rainshelter ranges from 2.5°C to 3.6°C. The similar results were obtained by Parvej *et al.* (2010).

2.4 Weather parameters under different growing conditions

According to Ganesan (2002), the mean monthly temperatures at 8 AM and 2 PM during January to October were found to be higher by 2^0 inside the greenhouse than in the open field and the higher temperature during daytime was due to trapping of short wave radiation in the greenhouse under partially closed conditions. Similar finding was reported by Nimje and Shyam (1993).

Ganesan (2002) reported that the Relative humidity was always higher in the open field during January to May and September to October but it was higher inside the greenhouse in the months of June and August, while the relative humidity was similar in July at 8 am in the both the conditions also observed almost a similar trend at 2pm was also observed but only from August to September. The relative humidity was higher in greenhouse condition. However, relative humidity was similar in the months of January and March in both the conditions at 2 pm. The lower relative humidity inside the greenhouse may be due

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to proper ventilation. Nimje and Shyam (1993) observed that the relative humidity was higher inside the greenhouse than in the open field condition.

Ganesan (2002) reported that the light intensity in the greenhouse was lower than in the field. Kaname and Itagi (1973) also found similar results for tomato cultivation under protected cultivation.

Nimje and Shyam (1993) observed that the relative humidity was higher inside the greenhouse than in the open field condition which resulted in increased infestation for vegetable crops.

Dinar and Rudich (1985) reported that higher temperatures in the greenhouse, affect several physiological and biochemical processes of tomato crop associated with yield reduction.

Kratky *et al*, (2013) discovered that shading of ginger reduces wilting during the hottest part of the day, and this would be expected to positively influence yields. However, shading caused reduced rhizome yields in the study. Covering the crop with a permanent shade screen reduces light throughout the day, including those periods (early to mid-morning and later afternoon) when light intensity is less than optimal for the maximum photosynthetic rate, and this negative effect appears to predominate over any positive effects of shading.

Hossain *et al.* (2009) reported that turmeric grown under lower RLI (Relative Light Intensity) had increased vegetative parameters, and a higher shoot biomass also found that shoot biomass increased with the increasing plant height, leaf number and tiller number of turmeric.

2.5 VALUE ADDITION IN GINGER

Ginger is seasonal in nature and available in large quantities during the peak season in the local market. In relation to spice and /or food, two problems arise in ginger cultivation. One is insufficient production and the other is post-harvest losses. If spoilage/post-harvest losses could be reduced to an acceptable level by proper preservation, farmers would get proper price of their products and thus be encouraged to increase yield and production. Only a small portion of ginger produced is processed and preserved by housewives and small processors by traditional method like sun drying. Thus, it is seen that the primary obstacle to production and consumption of increased amount of spices is the lack of suitable preservation method.

According to Okafor and Okafor (2007), dried ginger is traded traditionally in whole split form is used in wide range of foods when grounded into powdery form and used for preservation of meat, baking spice, soups and puddings

2.5.1 Ginger candy

Anis *et al.* (2012) conducted experiment to develop preserve and candy from fresh ginger and studied their storage life. The preserve was made from 60%, 65% and 70% sugar concentration. The candies were made from 65%, 70% and 75% sugar concentration. Among them, the best preserve and candy were identified on the basis of overall acceptability. The study showed that the color, flavor, texture and overall acceptability among the preserves and among the candies were different. The preserve (GP70) made from 70% and the candy (GC75) made from 75% sugar concentration was best among others of the similar product. Higher concentration of sugar and slower processing gives higher acceptability for preserve and candy. Among different changes, moisture concentration was prominent during preparation of preserve and candy. The moisture content was 42.0% and 37% for preserve and candy respectively which were nearly half of the initial concentration of fresh ginger. The storage stability of candy (90 days) was higher than storage stability of preserve (60 days).The color, flavor and fungal growth of candy were acceptable as there were no changes up to 90 days of storage. The remarkable change was noticed at 120 days of preservation and the candy remarked as unacceptable to consume. The changes occurred possibly due to fermentation in presence of fungus.

Nath *et al.* (2013) reported standard protocol for ginger candy preparation. The experimental parameters considered were slice thickness (5.0-25.0 mm) and blanching duration (10-30 min) followed by dipping in 40°B and 75°B sugar solutions containing 2.0% citric acid respectively, for 1 and 2 h at 95°C and dried at 60°C for 1 h. RSM design was considered for this experiment and final products were evaluated for their textural properties, TSS, acidity, TSS:acid ratio, taste score and overall acceptability. The optimum product qualities in terms of hardness (2.08 kg), TSS (73.4%), acidity (1.31%), TSS:acid ratio (56.3), taste score (7.98) and overall acceptability (8.07) were obtained for slice thickness of 10.9 mm and blanching time of 24.9 min.

Sivakumar (2013) made attempt to standardize amla sweet candy with different blanching time viz., 5, 10 and 15 minutes. The prepared sweet candies were standardized on the basis of sensory evaluation. Among these, a candy prepared with 10 minutes blanching time treatment was found to be the best.

2.5.2 Ginger flakes

Being as perishable due to high moisture content, chemical and structural changes during storage and spoilage due to micro organisms accounts for post harvest losses to the ginger growers. The preservation methods such as dehydration, steeping (salt solution) and pickling can be successfully adapted to preserve fresh ginger for off-season.

According to Yadav and Singh (2014), Osmotic dehydration is preferred over other dehydration methods due to their color, aroma, nutritional constituents and flavor compound retention value. The solutes used in this method are generally sugar syrup with fruit slices or cubes and salt (sodium chloride) or brine with vegetables. However in general, vegetables after washing and peeling (if required) are reduced in appropriate size by cutting or slicing. After size reduction pretreatment like blanching (dipping the pieces in boiling water) is carried out. After this osmotic treatment is carried out usually in brine or other osmotic agents.

An *et al.* (2013) reported that osmotic dehydration of ginger slices could effectively be used as a pretreatment prior to conventional drying to remove a large portion of moisture (58.8%, wb) at the low temperature, which is beneficial to maintain the natural property of the product

Manafi *et al.* (2010) studied osmotic dehydration of Apricot using salt-sucrose solutions and results revealed that the best temperature and concentration that had a high water loss to solid gain ratio and an acceptable taste were 40˚C and 5%, respectively.

2.5.3 Ginger powder

Ginger powder is used to flavor all kinds of foods. It also finds direct application in a variety of food products (Balakrishnan 2005).It is included in foods such as cakes, ginger cookies, gingerbread, pies, jams, candy, beer, and ginger ale soda. Ginger powder is often added to savory dishes such as meats, vegetables, rice, tofu, marinades, sauces, curry pastes, stir fries, ginger tea and soups. Ginger powder is a perfect addition to marinades. Addition of ginger powder to dishes at the beginning of cooking increases the flavor.

Ginger powder is made by pulverizing the dried ginger to a mesh size of 50 to 60 (Ravindran and Nirmalbabu 2005). Pulverization is a physical unit operation whose phenomenon involves size reduction or crushing of the cells and separation of granules.

2.5.4 Physico –chemical parameters

Peeling

Peeling of ginger is an important step and a prerequisite for preparation of various value added products. After washing the ginger rhizomes are subjected to peeling operation. Indigenously, peeling of ginger is done by scrapping with sharpened bamboo stick. Ginger are irregular in shape and not in a spherical geometry, therefore peeling process is a very tedious, time consuming and labour intensive operation. Ginger peeling is done manually inspite of machines developed (Agarwal *et al*, 1987; Ali *et al*, 1991).

Moisture

Aonla dried to a moisture content of 7.20 per cent by using a solar dehydrator and reported a progressive decline in moisture during storage of 135 days (Tirupathi *et al.* 1998).

Sagar *et al.* (2000) reported a rapid change in moisture content of mango powder up to two months of storage at ambient and low temperatures.

According Sivakumar (2013) there was decrease in moisture content during storage in amla sweet candy.

TSS

According to Sivakumar (2013), in amla sweet candy total soluble solids (TSS) and total sugar decreased from 58.20 to 57.10 °B and 45.74 to 45.13 per cent respectively, after nine months of storage.

Mishra *et al.* (2013) observed that in bael candy the percentage total soluble solids (TSS) increased gradually during storage in both types of packaging containers. However, the rate of change of TSS was faster in glass jars than polythene pouches. At the initial stage, the TSS value was 73.8% in both types of containers but at the end of observation (8 month after storage), the TSS of candy stored in glass jar was 78.5 % while in polythene pouch it was 75.2 %.

Titratable acidity

Tirupathi *et al.* (1998) reported a decreasing trend in the acidity of dehydrated aonla during storage.

Mishra *et al.* (2013) reported that the per cent TSS, acidity and browning of bael candy increased while ascorbic acid decreased during storage in both types of containers. The organoleptic quality of candy was extremely good in polythene pouches up to 4 months while only one month in glass jar.

2.5.6 Microbial count

Menon (2000) claimed low microbial counts in dehydrated fruits and vegetables, dried to moisture content less than 3 per cent after blanching and drying.

Sivakumar (2013) found that in amla sweet candy showed a very slight increase in microbial load during the storage period. The initial bacterial, fungal and yeast counts were 1x10-3g, 1x10-2g and 1x10-2g respectively, which had increased to 4x10-3g bacterial counts, 3x10-2g fungal count and 3x10-2g yeast count at the end of the storage period.

Gupta and Shukla (2017) conduted study on preparation and quality evaluation of dehydrated carrot and onion slices and noticed that the finished product had no mould count which means the product remained microbiologically sterile during entire storage period. It was observed that the products dehydrated at 50°C and 60°C were best among all the samples tried.

2.5.7 Sensory evaluation

Sivakumar (2013) observed that in amla sweet candy, organoleptic scores slightly decreased with advancement in the storage period. The organoleptic scores of colour, appearance, texture, taste and overall acceptability were 8.9, 8.8, 8.6, 8.8 and 8.7 respectively at initial study period. After nine months of storage the organoleptic scores of amla sweet candy was recorded as 8.0, 7.9, 7.8, 8.0 and 7.9 for colour, appearance, texture, taste and overall acceptability, respectively.

Mishra *et al.* (2013) reported that the acceptability of bael candy stored in polythene pouch was up to 4 months and in glass jar it was only one month without any change. The acceptable and marketable quality of candy was up to 4 months in glass jar while up to 8 months in polythene pouch. Overall, better organoleptic quality of candy was also rated high in polythene pouch than the candy stored in glass jar.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The study on "Screening ginger (*Zingiber officinale* Rosc.) genotypes under different growing conditions and for value addition" was carried out at the Department of Plantation Crops and Spices, College of Horticulture, Vellanikkara, Thrissur, Kerala during 2015-2018. Main aspects focused in the study are as follows:

1. Screening ginger genotypes for yield and quality
2. Performance of ginger genotypes under different growing conditions
3. Quality profiling of ginger genotypes under different growing conditions and different maturity stages
4. Screening ginger genotypes for product preparation

The details of the experimental materials used and methodology adopted for conducting the study are presented in this chapter.

3.1 SCREENING GINGER SOMACLONES FOR YIELD AND QUALITY

3.1.1 Experimental material

In the DBT funded project entitled "Exploitation of somaclonal variation for disease tolerance and high yield in ginger" (2006) operated in Department of Plantation Crops and Spices, College of Horticulture, Vellanikkara, somaclones were developed and maintained in the field. They were developed through indirect methods of regeneration from two induced polyploids of ginger (Z-0-78 from Himachal Pradesh treated with 0.25% colchicine by injection method and Z-0-86 from Rio-de-Janeiro treated with 0.1% colchicine by hole method) and diploid cultivar Himachal Pradesh.

Materials used in the study consist of ten somaclones and three varieties (Plate 1) namely, Rio-de-Janeiro, Himachal and Aswathy (Single plant selection from Rio-de-Janeiro). Details of somaclones used in the experiment and their mode of regeneration are given below.

SE 8626

SE 8683

C 8626

CHP 118

C 78284

SE 86102

SE 8642

C 8632

CHP 99

CHP 282

(Control varieties)

Rio-de-Janeiro

Himachal

Aswathy

Plate 1 . Ginger genotypes selected for the evaluation of yield and quality

Details of somaclones selected for the study

S.No.	Parents	Somaclones	Mode of regeneration
1	Z-0-78	C 86 26	Indirect organogenesis
2		C 86 32	
3	Z-0-86	C 78 284	
4	Himachal Pradesh	CHP 282	
5		CHP 118	
6		CHP 99	
7	Z-0-86	SE 86 83	Indirect embryogenesis
8			
9		SE 86 26	
10		SE 86 42	
		SE 86 102	

3.1.2 Field experiment

The selected ten somaclone sand three check varieties were raised in the field of Dept. of Plantation Crops and Spices during 2015-16. The field was prepared by ploughing and raised beds of size 2 m x1m were taken with an interchannel width of 40 cm. Rhizome bits of 15- 20 g were used for planting. The experimental plot was laid in Randomized Block Design with three replications. The crop was managed as per Package of Practices, Recommendations of Kerala Agricultural University (KAU, 2011).The clones planted in May were harvested in January 2016. The genotypes selected for this study are SE 86 26, SE 86 83, C 86 26, CHP 118, C 78 284, SE 86 102, SE 86 42, C 86 32, CHP 99 and CHP 282 and three check varieties such as Rio- de – Janeiro, Himachal and Aswathy.

3.1.3. Observations

Plants were randomly selected from each genotype and observations on the quantitative and qualitative characters were recorded.

3.1.3.1 Morphological Characters

a. ***Number of days for sprouting***

Observed daily for the emergence of sprout and the duration of the sprouting was recorded as the days taken by seed rhizomes from the day of planting to sprout emergence.

b. ***Plant height***

The height of the plant from the base of the tiller to the tip of the topmost leaf was measured and expressed in centimetres.

c. ***Number of tillers plant^{-1}***

Number of tillers was recorded by counting the number of fully emerged ones.

d. ***Number of leaves shoot^{-1}***

Number of leaves was recorded by counting the number of fully opened leaves of the highest tiller.

e. ***Leaf area (cm^2)***

Leaf area was calculated using the equation A= -24 + 3.312 x L, where L is the length of the upper fourth opened leaf and 'A' is the leaf area (Sheeba, 1996).

f. ***Total number of leaves plant^{-1}***

Total number of leaves was recorded by counting the number of fully opened leaves of each tiller.

3.1.3.2 Rhizome Characters

a. ***Mother rhizome weight (g)***

The main axis arising from the seed rhizome was taken as mother rhizome and was weighed.

b. ***Number and weight (g) of primary, secondary, tertiary and quaternary rhizomes***

The number and weight o fingers arising from the mother rhizome was counted and weighed.

c. Fresh rhizome yield per plant, plot and hectare

The harvesting of rhizome was done at seven months after planting by uprooting individual clumps. Yield per plant (g), plot (kg) was recorded and per hectare yield was computed (tonnes).

d. Dry rhizome yield (kg plot^{-1}and ha^{-1})

Per plot (kg) and per hectare yield of dry rhizome (tones) was computed from theper plot and per hectare fresh yield and driage per cent.

e. Dry recovery/ Driage

One kilogram of fresh rhizome was rough peeled and sun dried initially and later in hot air oven (55^{0}C) till a constant weight was obtained. Dry recovery of rhizome was expressed in percentage.

3.1.3.3 Pest and disease incidence

a. Pest incidence

Incidence of stem borer (*Conogethes punctiferalis*) was recorded as the number of infected tillers per clump and was expressed as percentage of number of tillers infected to total number of plants (Devasahayam *et al.*, 2010).

b. Disease scoring

Per cent incidence of Rhizome rot was calculated by using the formula,

$$PDI = \frac{\text{Number of plants infected}}{\text{Total number of plants observed}} \times 100$$

3.1.3.4 Biochemical Characters

Rhizome of the selected genotypes, replicated twice, were analyzed for quality attributes such as driage and content of volatile oil, oleoresin and crude fibre.

a. Estimation of volatile oil (%)

Volatile oil was estimated by water cum steam distillation method using Clevenger apparatus as per AOAC (1980 b). The recovery of volatile oil was expressed as percentage. Twenty five grams of coarsely ground powder from each somaclone was distilled for three hours for estimation of volatile oil. From the dry rhizomes per hectare oil content, oil yield per hectare was computed.

b. Estimation of oleoresin (%)

The content of oleoresin in the samples was estimated using Soxhlet method of extraction as per AOAC (1980 b). Five grams of powdered sample was refluxed with 125ml of acetone. Extraction was continued till the solvent becomes colourless. The acetone extract of the sample was transferred to a pre-weighed beaker and the solvent was evaporated and weight of the beaker along with the extract was recorded. The recovery of oleoresin was expressed in percentage. From the dry rhizome yield, per hectare and oleoresin content, oleoresin yield per hectare was computed.

c. Estimation of crude fibre (%)

The content of crude fibre was estimated as suggested by Sadasivam and Manickam (2010) and expressed in percentage. Two gram of ginger powder was boiled with 200 ml of sulphuric acid for 30 minutes, filtered through muslin cloth and washed with distilled water to remove acidic nature. Subsequently boiled with 200 ml of sodium hydroxide solution for 30 minutes and it was again filtered and washed with 25 ml alcohol. The residue obtained after final filtration was weighed, incinerated, cooled and weighed again. The content of crude fibre was given by the difference in weight expressed as percentage.

d. Estimation of starch (%)

Starch was estimated colorimetrically using anthrone reagent, as suggested by Sadasivam and Manikam (2010). Weighed 0.3 g of the sample and extracted with 80 per cent ethanol to remove sugars. Residue was repeatedly extracted with hot 80 per cent ethanol to remove the sugars completely. The residue was dried over a water bath and added 5 ml water and 6.5 ml of 52 per cent perchloric acid and extracted in the cold for 20 minutes. Centrifuged the sample and re-extracted with fresh perchloric acid. The supernatant was pooled and made up to 100 ml. Pipetted out 0.2 ml of the supernatant and made up to one ml with water and added 4 ml of anthrone reagent, heated for 8 minutes, cooled and read the OD at 630 nm.

e. Chemoprofiling

Analysis of non volatile pungent principles (oleoresin) by HPLC was done at the Quality Evaluation Laboratory (QEL) of Spices Board, Cochin.

Methanolic extract of dried ginger rhizomes from 14 somaclones were prepared. After preparation shake it well and kept for two hours, after 2 h it was again shaken and kept for twelve hours without disturbance. Twenty ml of supernatant was taken and it was concentrated to 2 ml on water bath and made up to 5 ml in calibrated test tube. Twenty microliter of this sample was taken to analyze gingerol and other pungent compounds using Shimadzu HPLC with Array Detector on a C18 column (4.6 x 250 mm, 5 μm). The HPLC conditions were: 280nm as detector wave length, 1ml of flow rate and 20 microliter volume of injection. The mobile phase was adjusted as follows: Acetonitrile: Water (65:35) with 1% acetic acid in water. Gingerol and related compounds were quantified in the samples by using the regression of peak areas and expressed in percentage on dry weight basis.

3.1.3.5 Physiological characters

a. Chlorophyll index

SPAD meter was used to find the chlorophyll index, readings were taken from the fully opened 4^{th} leaf of the main shoot.

b. Photosynthetic rate

Photosynthetic rate was measured by using the instrument, infrared gas analyzer (Model LI-6400 of LicorInc. Lincoln, Nebraska, USA) at vegetative stage of the plant and the readings were taken during 9 to 10 am and expressed as μ mol CO_2 m^{-2} s^{-1}.

c. Transpiration rate

Transpiration rate was measured by using the instrument, infrared gas analyzer (Model LI-6400 of LicorInc. Lincoln, Nebraska, USA) at vegetative stage of the plant and the readings were taken during 9 to 10 am and expressed as μ mol H_2O m^{-2} s^{-1}.

d. Stomatal conductance

Stomatal conductance was measured by using the instrument, infrared gas analyzer (Model LI-6400 of LicorInc. Lincoln, Nebraska, USA) at vegetative stage of the plant and the readings were taken during 9 to 10 am and expressed as m μ mol m^{-2} s^{-1}.

3.1.3.6 Weather Parameter

Weather parameters like minimum and maximum temperature (^{0}C) were taken using whirling psychrometer, relative humidity (%) was computed for those readings and light intensity (Lux) was recorded using Lux metre.

a. Rainfall (mm)

Rainfall (mm) data of the growing period was obtained from the department of Agricultural meteorology of College of Horticulture, Kerala Agricultural University.

3.2 PERFORMANCE OF GINGER SOMACLONES UNDER DIFFERENT GROWING CONDITIONS

Promising four somaclones identified from the department along with one KAU released variety (Aswathy) as control were raised under two different growing conditions such as rain shelter and open field (Plate 3). The field was prepared by ploughing and raised beds of size 2m x1m were taken with an interchannel of 40cm width. Rhizome bits of 15- 20 g were used as seed material The crop was raised in May- June and maintained as per POP recommendations of KAU (KAU, 2011).The details of the genotypes selected for this study is given below (Plate 2).

Genotypes selected for performance evaluation under rain shelter and open field .

Sl.No.	Genotypes
1	SE 86 81
2	SE 86 40
3	SE 86 131
4	SEHP 9
5	Aswathy

The selected five genotypes were grown under two growing conditions *viz.*, in open field and rain shelter. Experiment was conducted in Randomized Block Design with four replications during 2015-16.

3.2.1 Observations

The observations on morphological characters, rhizome characters, pest and disease scoring, physiological characters and weather parameters were recorded same as mentioned in 3.1.3.

SE 86 81

SE 86 40

SEHP 9

SE 86 131

Aswathy

Plate 2. Ginger genotypes selected for growing under different conditions

3.3 QUALITY PROFILING OF GINGER GENOTYPES UNDER DIFFERENT GROWING CONDITIONS AND DIFFERENT MATURITY STAGES

Five ginger genotypes *viz.,* SE 86 81, SE 86 40, SE 86 131, SEHP 9 and Aswathy, grown under two growing conditions (open field and rainshelter) from 2nd experiment were utilized for this study. Samples at two maturity stages (vegetable maturity and full maturity) were collected from experiment 2 for analysing quality parameters. The experiment was conducted in Completely Randomized Design with two replications.

3.3.1 Observations

Quality parameters *viz.,*volatile oil, oleoresin and crude fibre were estimated. Chemoprofiling of oleoresin was also done.

a. Estimation of volatile oil (%)

Same as mentioned in 3.1.3.4 (a)

b. Estimation of oleoresin (%)

Same as mentioned in 3.1.3.4 (b)

c. Estimation of crude fibre (%)

Same as mentioned in 3.1.3.4 (c)

d. Estimation of starch

Same as mentioned in 3.1.3.4 (d)

e. Chemoprofiling of oleoresin

Same as mentioned in 3.1.3.4 (e)

f. Analysis of non volatile pungent principles by HPLC

Same as mentioned in 3.1.3.4 (f)

3.4 SCREENING GINGER GENOTYPES FOR PRODUCT DEVELOPMENT

Products like candy, flakes and powder were developed from ginger somaclones.

Open field

Rain shelter

Plate 3. Different growing conditions

3.4.1. Preparation of ginger products

a. Ginger candy

Ginger candy was prepared from 5 month old immature fresh ginger rhizomes. Eleven genotypes (10 somaclones and 1 released variety) with variable fibre content were selected. Five kg of rhizomes from selected somaclones were cleaned to remove soil particles. Peeling was done manually and after peeling, rhizomes were cut in to small sized pieces. Syruping was done with sugar solution having 50^0 Brix (TSS) for one day. This process was repeated to raise the strength of syrup from 50 to 55 - 60^0 and finally to 70^0 TSS. The entire process took 4 days to complete and on 4^{th} day sugar syrup was drained and the candy pieces were taken out, washed in lukewarm water. After that drying was done at 45^0 C for 2 h with 30 mintues interval. Further drying was done for one hour at 50^0 C and after 30 minutes drying was continued at 55^0 C, till the moisture content of candy reached to 8 to 10 %. The candy pieces were dusted with dextrose and passed through seive to remove extra dextrose and packed in HDPE pouches (Plate).

b. Ginger Flakes

Ginger flakes were prepared from 5 month old immature fresh ginger rhizomes. Ten somaclones with variable fibre content from experiment 1were selected along with one released variety Aswathy. Five kg of rhizomes from selected somaclones were cleaned to remove soil particles. Peeling was done manually and after peeling, rhizomes were cut in to small sized slices (4 mm thickness). Slices were then rolled in 2 percent salt and dried in a drier at 50 ^{0} C temperature until the dried product gave constant weight and packed in HDPE covers for storage (Plate).

c. Ginger Powder

Ginger powder was prepared from 7 month old mature fresh ginger rhizomes. Ten somaclones with variable fibre content were selected along with one check variety. Five kg of rhizomes from selected somaclones were cleaned to remove soil particles. Peeling was done manually and after peeling, rhizomes were cut in

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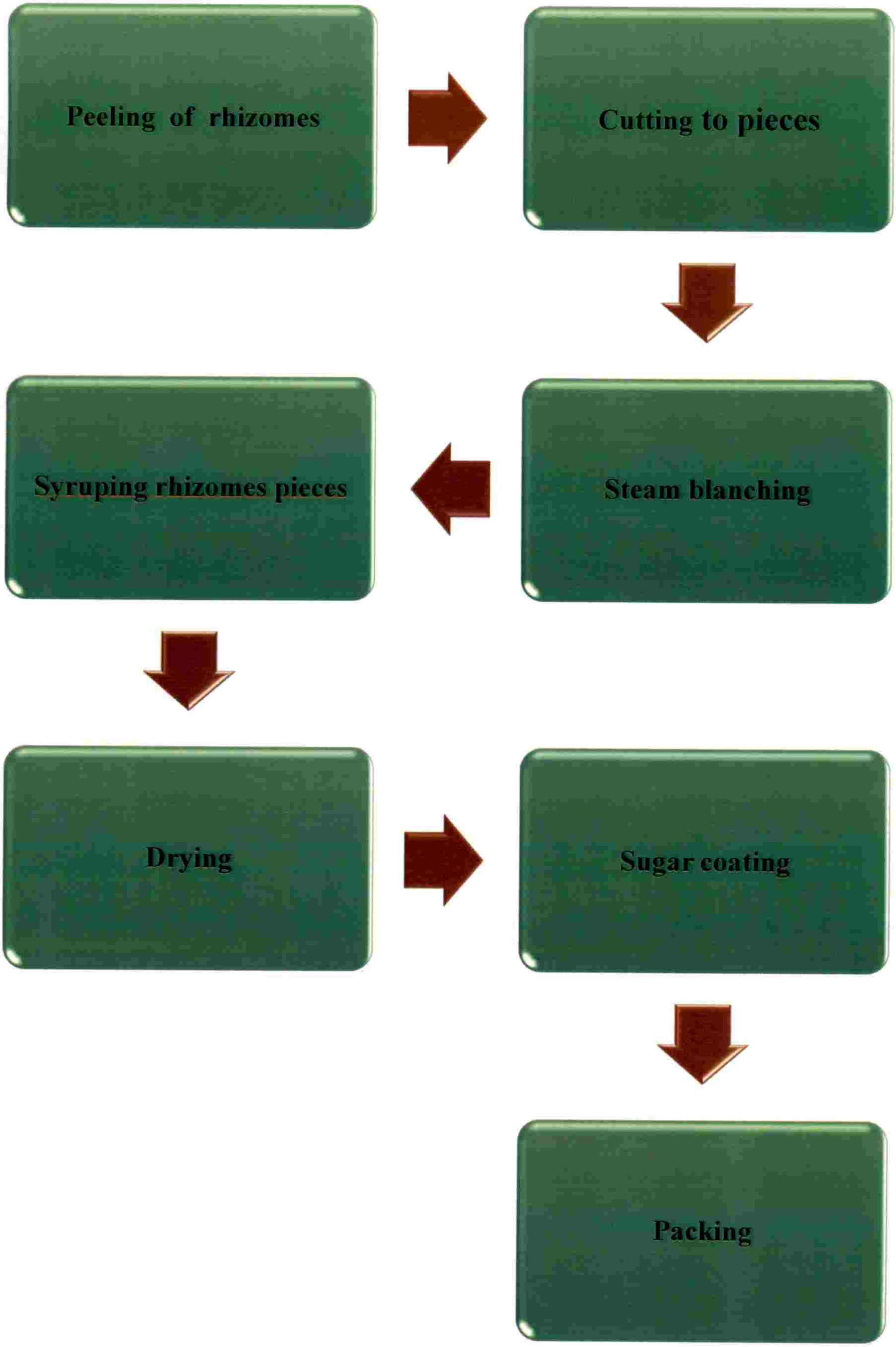

Plate 4. Preparation of ginger candy

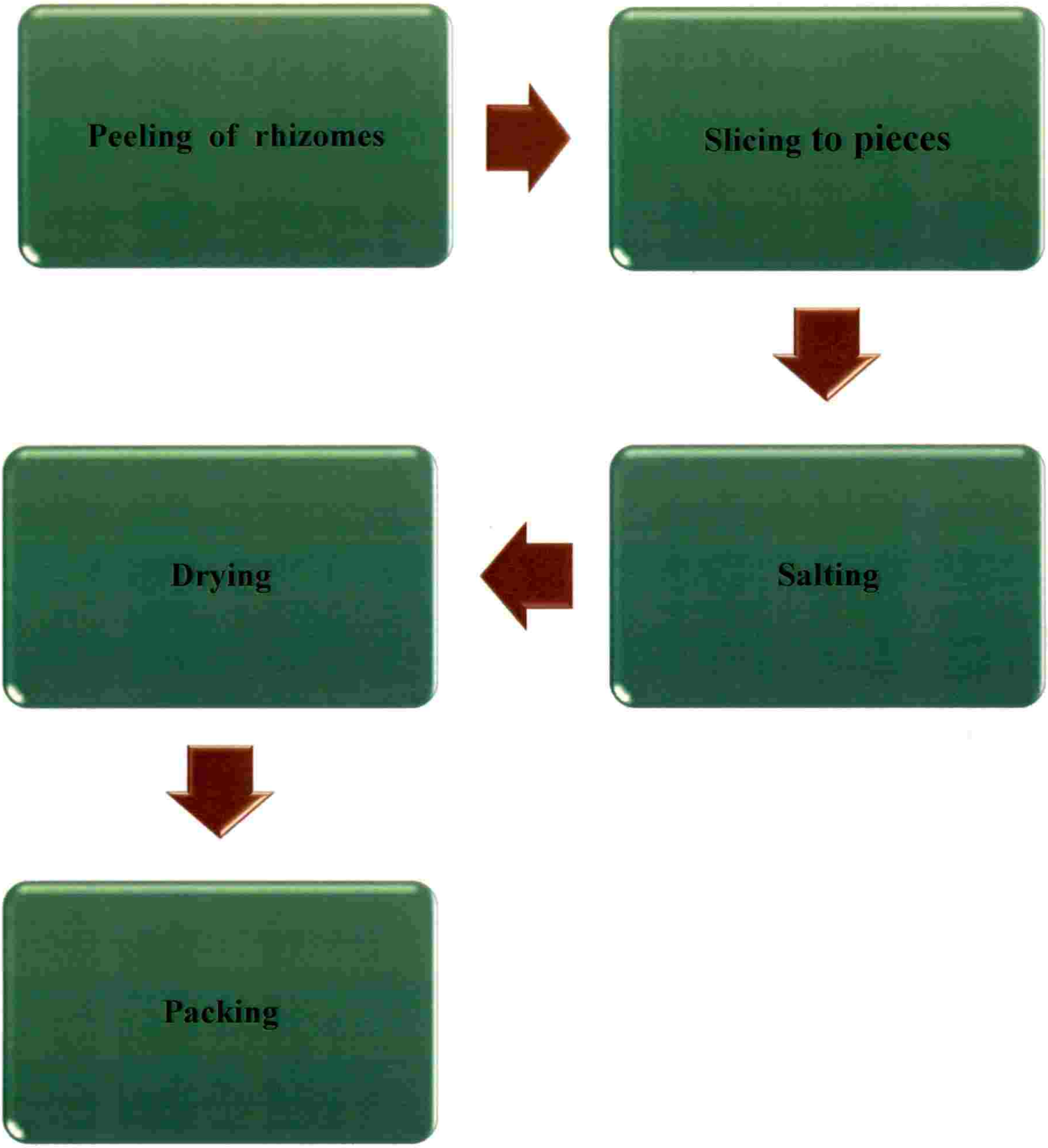

Plate 5. Preparation of ginger flakes

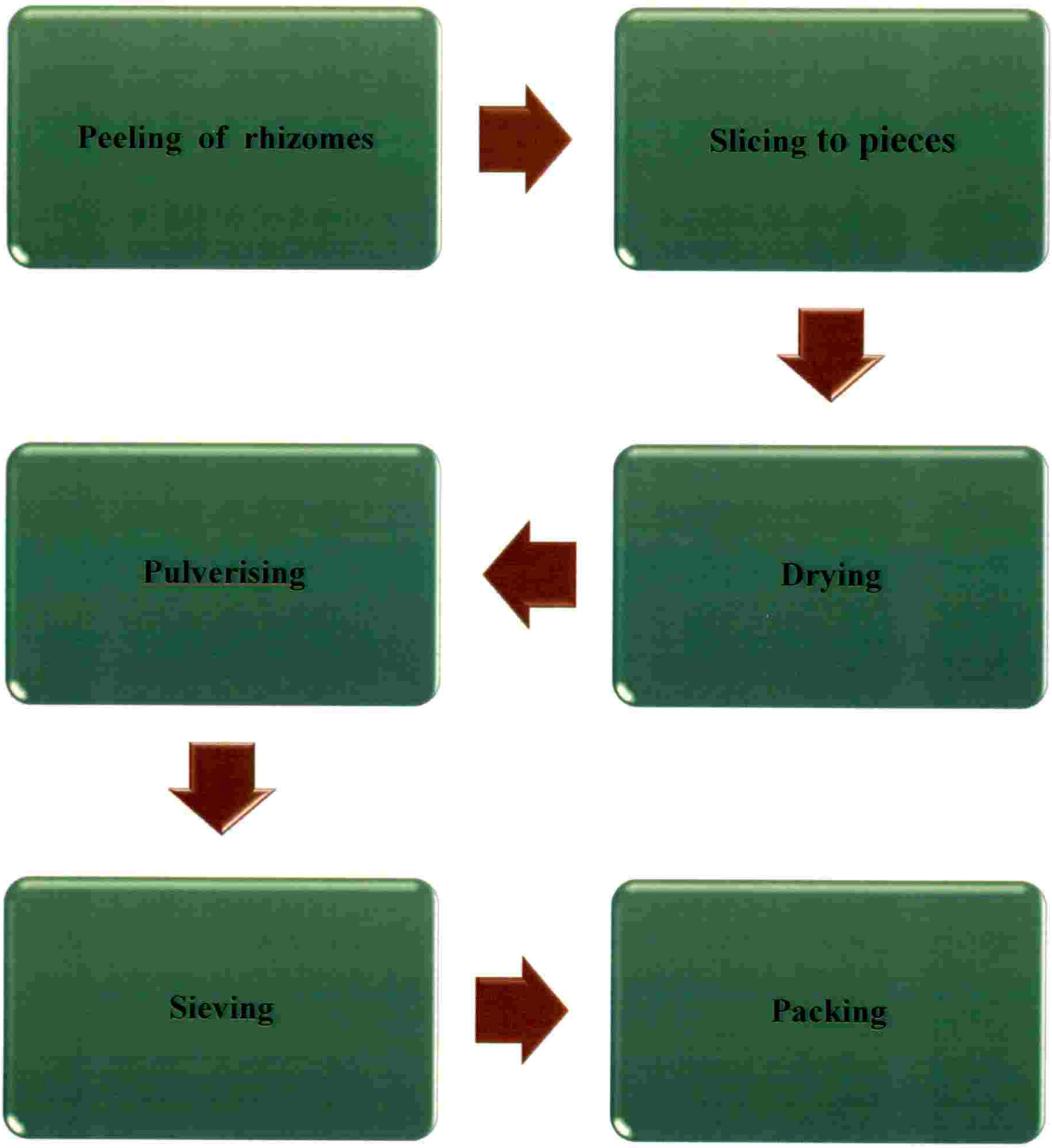

Plate 6. Preparation of ginger powder

to small thin slices and dried in a drier at 50 ^{0} C temperature to constant weight. Dried ginger was then pulverized and sieved through a 50 mesh sieve and packed in HDPE covers (Plate 10).

3.4.2. Observations

a. Easiness in peeling

It was assessed based on time required for manual peeling 100 grams of fresh ginger rhizome of individual treatments.

b. Recovery (%)

Weight of finished candy over initial weight of rhizomes was calculated and expressed as recovery percentage.

$$\text{Recovery percentage} = \frac{\text{Weight of candy after drying}}{\text{Initial weight of rhizomes}} \times 100$$

3.4.3 Storage stability of ginger candy, flakes and powder

The prepared products were packed in HDPE (High Density Poly Ethylene) covers and were stored in room temperature (26 ± 3^{0}C) for six months. Samples were drawn before storage and 2, 4 and 6 months after storage to analyze the physical parameters, chemical parameters, microbial load and organoleptic quality.

3.4.3.1 Observations

3.4.3.1.1 Physical parameters

a. Moisture content (%)

Moisture content of the product was estimated by oven dry method. Ten grams of the product was kept in hot air oven and dried to constant weight. The moisture content was calculated and expressed in percentage (Ranganna, 1995).

b. Colour

Colour of ginger candy, flakes and powder was noted using the Royal Horticulture Society colour charts (Edition V).

3.4.3.1.2 Biochemical parametrs

a. Total Soluble Solids (TSS)

TSS was measured by using a hand refractometer (range 38-92^0 Brix for candy) and expressed in degree Brix (^{0} Brix).

b. pH

The pH was determined in digital type pH meter.

c. Titratable acidity

The titratable acidity was determined by titrating known weight/volume of the sample against 0.1 N NaOH solution using phenolphathalein as indicator. The acidity was calculated and expressed as per cent citric acid (AOAC, 1965 a).

3.4.3.1.3 Microbiological analysis

The quantitative assay of microflora present in ginger candy, fakes and powder was carried out by serial dilution plate count method as described by Agarwal and Hasija (1986). Ten grams of sample was added to 90 ml distilled water and shaken well to form suspension. From this, 1 ml was transferred to a test tube containing 9ml distilled water. This gave a dilution of 10^{-2} and similarly 10^{-3},10^{-4},10^{-5} and10^{-6} dilutions were also prepared.

Ginger candy, flakes and powder were subjected to microbiological analysis immediately after preparation and also 2, 4 and 6 months of storage. The samples were analyzed for the population of bacteria, mould and yeast in standard plate count. Nutrient Agar media was used for bacteria, Rose Bengal Agar media for mould and Sabouraud's Dextrose Agar media for yeast. The microbial counts were expressed in cfu/g of sample.

a. *Estimation of bacterial population*

Bacterial population was estimated using 10-^{5} dilution on Nutrient Agar medium. One ml of 10-^{5} dilution was pipetted in a sterile petridish using a

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micropipette. About 20 ml of melted and cooled Nutrient Agar (NA), media was poured into petridish and it was swirled. After solidification, the petri plates were incubated at room temperature for 48 h. Two petridishes were kept as replicate for each sample. The bacterial colonies developed were counted and expressed as cfu/g sample.

b. *Estimation of mould population*

Mould was estimated using 10-^{3} dilution on, Rose Bengal agar. One ml of 10-^{3} dilution was pipette into a sterile petridish using a micropipette. About 20 ml of melted and cooled Rose Bengal Agar media was poured in to petridish and it was swirled. After solidification, it was kept for incubation at room temperature. Two petridishes were kept as replicate for each sample. The petriplates were incubated at room temperature for 4-5 days .The mould colonies developed were counted and expressed as cfu/g sample.

c. Estimation of yeast population

Yeast population was estimated using 10^{-3} dilution on, Sabouraud's Dextrose Agar media. One ml of 10^{-3} dilution was pipetted into a sterile petridish using micropipette. About 20 ml of melted and cooled Sabouraud's Dextrose agar was poured into petridish and it was swirled. After solidification, it was kept for incubation at room temperature. Two petridishes were kept as replicate for each sample. The petriplates were incubated at room temperature for 4-5 days .The yeast colonies developed were counted and expressed as cfu/g sample.

3.4.3.1.4. Sensory evaluation

The candy, powder and flakes prepared were evaluated for color, flavor, texture and overall acceptability by a 15 panel of testers. All the testers were briefed before evaluation. The samples were randomly coded and presented to panelists. The test panelists were asked to rate the candy, flakes and powder presented to them on a 9 point hedonic scale with the ratings of: 9 = Like extremely; 8 = Like very much; 7 = Like moderately; 6 = Like slightly; 5 =

Neither like nor dislike; 4 = Dislike slightly; 3 = Dislike moderately; 2 = Dislike very much; and 1 = Dislike extremely. The result was analyzed by statistical software (SPSS- K related samples).

RESULTS

4. RESULTS

The study entitled, "Screening ginger (*Zingiber officinale* Rosc.) genotypes under different growing conditions and for value addition" was carried out at the Department of Plantation Crops and Spices, College of Horticulture, Vellanikkara, Thrissur, Kerala during 2015-2018. The data collected were statistically analyzed and the results of four experimentations and laboratory estimations are presented in this chapter.

4.1 SCREENING GINGER SOMACLONES FOR YIELD AND QUALITY

4.1.1 Morphological Characters

Morphological characters and yield attributes of 10 somaclones along with three check varieties (Rio- de –Janeiro, Himachal and Aswathy) were recorded for a period of six months after planting (MAP). Morphological characters recorded include number of days for sprouting, plant height, number of tillers per plant, number of leaves per shoot, leaf area and total number of leaves per plant.

4.1.1.1 Number of days for sprouting

There was significant difference among the somaclones on the number of days for sprouting (Table 1). The minimum number of days (13.67) for sprouting was recorded by Aswathy and was on par with Himachal (15.33), SE 86102 (16.00), Rio-de-Janeiro (16.33) and SE 8626 (16.33). CHP 99 and C 8626 recorded the maximum number of days (23) for sprouting. Days for sprouting were more than 20 in C 8626, SE 8642, CHP 282 and CHP 99.

4.1.1.2 Plant height

Plant height was recorded at monthly intervals and the data is furnished in Table 2. There was significant difference among the somaclones on the plant height and it ranged between 17.75 cm (C 8626) and 43.76 cm (CHP 118) during 2 MAP. Plant height increased with age of the plant. During 3rd month after planting, maximum (85.03 cm) was recorded by somaclone SE 86102 and

Table 1. Days for sprouting in ginger genotypes

Genotypes	Number of days for sprouting
SE 8626	16.33
SE 8683	16.67
C 8626	23.33
CHP 118	18.67
C 78284	18.33
SE 86102	16.00
SE 8642	20.67
C 8632	18.33
CHP 99	23.67
CHP 282	21.00
Rio-de-Janeiro	16.33
Himachal	15.33
Aswathy	13.67
CD (0.05)	2.71

Table 2. Plant height of ginger genotypes at different growth stages

Genotypes	Plant height (cm)				
	2 MAP	3 MAP	4 MAP	5 MAP	6 MAP
SE 8626	34.51	58.45	67.99	82.58	87.37
SE 8683	35.71	68.56	72.79	83.87	84.50
C 8626	17.75	35.20	73.88	82.11	85.47
CHP 118	43.76	79.47	73.01	87.60	90.34
C 78284	39.54	58.67	61.53	72.00	75.42
SE 86102	40.67	85.03	92.42	103.8	107.38
SE 8642	25.39	49.66	70.49	77.53	80.20
C 8632	37.25	69.08	76.57	85.21	87.55
CHP 99	29.94	65.42	72.49	77.05	82.02
CHP 282	39.88	79.07	82.33	90.10	92.23
Rio-de-Janeiro	29.00	65.15	70.67	83.52	85.38
Himachal	42.29	77.03	82.47	89.63	92.07
Aswathy	37.81	58.67	66.55	69.33	72.55
CD (0.05)	5.05	5.19	2.54	1.67	5.52

MAP- Months After Planting

minimum plant height (35.20 cm) was for somaclone C 8626. At 4 MAP, 5 MAP and 6 MAP somaclone SE 86102 recorded maximum plant heights (92.42, 103.80 cm and 107.38 cm respectively). Plant height was low in Aswathy at 5 MAP (69.33 cm) and 6 MAP (72.55 cm).

4.1.1.3 Number of tillers per plant

Mean values of the number of tillers per plant are furnished in the Table 3. The data revealed that the check variety Himachal recorded the highest value (3.73) followed by the somaclone SE 8642 (3.57) at 2nd MAP and the lowest was for somaclones SE 86102 and C 78284 (1.40). At 3MAP, Himachal recorded the highest value of 9.47, whereas C 8626 and CHP 282 recorded lowest value (3.67). At 4 MAP, the number of tillers ranged from 5.97 (CHP 282) to 12.33 (CHP 118). Numbers of tillers were more than 10 in SE 8683, SE 8626 and CHP 118 and less than 6 in CHP 282 (5.97). At 5 MAP, tiller number varied from 8.67 (SE 86102) to 15.67 (CHP 118). At 6 MAP, number of tillers were greater than 16 in SE 8626 (18.01), CHP 118 (20.33), SE 8642 (17.97) and C 8632 (16.93). At 4, 5 and 6 MAP, the somaclone CHP 118 recorded the highest values for number of tillers per plant (12.33, 15.67 and 20.33 respectively).

4.1.1.4 Number of leaves per shoot

The number of leaves per shoot was recorded at monthly intervals from 2 months after planting (MAP) and the data is furnished in Table 4. Significant difference was observed between somaclones in the number of leaves per shoot. The somaclone CHP 118 registered the highest value (8.07) at 2 MAP and was on par with SE 8626 (7.73), SE 8642 (7.60), C 8632 (7.50) and CHP 282 (7.43). The lowest value (5.23) was recorded by the somaclone CHP 99. At 3 MAP, somaclone CHP 118 recorded the highest value (15.33) for number of leaves per shoot and was on par with SE 8626 (13.83). During 4th MAP, somaclone CHP 118 recorded highest number of leaves per shoot with a value of 16.53. During 5th MAP, somaclone CHP 118 recorded highest value (20.33) for number of leaves per shoot and was on par with SE 8642 (19.33). At 6 MAP, maximum number of

Table 3. Tillers per plant in ginger genotypes at different growth stages

Genotypes	Number of tillers				
	2MAP	3MAP	4MAP	5MAP	6MAP
SE 8626	2.80	6.07	11.60	12.00	18.01
SE 8683	2.80	8.13	10.03	11.97	15.63
C 8626	2.53	3.67	9.97	11.33	14.83
CHP 118	1.60	6.73	12.33	15.67	20.33
C 78284	1.40	6.20	9.63	12.03	15.27
SE 86102	1.40	5.33	6.67	8.67	15.13
SE 8642	3.57	6.13	9.07	10.67	17.97
C 8632	1.97	7.68	9.93	12.83	16.93
CHP 99	2.40	6.40	6.93	10.67	11.23
CHP 282	1.73	3.67	5.97	8.97	15.01
Rio-de-Janeiro	2.13	7.07	7.03	11.33	11.56
Himachal	3.73	9.47	7.00	13.67	11.43
Aswathy	1.73	4.77	7.67	11.67	14.93
CD (0.05)	0.21	0.21	0.52	2.77	0.83

Table 4. Leaves per shoot in ginger genotypes at different growth stages

Genotypes	Number of leaves per shoot				
	2MAP	3MAP	4MAP	5MAP	6MAP
SE 8626	7.73	13.83	14.29	18.33	28.33
SE 8683	6.93	12.67	13.01	18.93	17.25
C 8626	4.97	9.97	11.90	15.13	16.43
CHP 118	8.07	15.33	16.53	20.33	28.67
C 78284	6.83	11.20	14.67	15.67	21.00
SE 86102	6.73	11.19	14.00	16.33	18.23
SE 8642	7.60	14.21	15.00	19.33	26.33
C 8632	7.50	12.50	14.01	14.67	26.07
CHP 99	5.23	9.50	13.20	17.27	16.87
CHP 282	7.43	11.50	12.50	18.00	16.93
Rio-de-Janeiro	6.25	10.31	13.33	18.60	17.89
Himachal	6.41	10.40	13.67	16.33	17.88
Aswathy	6.13	11.22	12.00	15.77	20.20
CD (0.05)	0.71	1.50	0.98	1.23	1.77

MAP- Months After Planting

leaves per shoot was observed in CHP 118 (28.67) and SE 8626 (28.33). Table 5 shows the total number of leaves per plant recorded by different somaclones during the growing period. It was found that there was significant difference among the somaclones on the total number of leaves per plant during the 2nd MAP. The somaclone SE 8626 registered the highest value (21.77) for this character and was on par with CHP 118 (21.03), SE 8642 (20.86), C 8632 (19.06) and SE 8683 (18.76). The lowest value (10.00) was recorded by the somaclone C 8626 and Rio- de- Janeiro. At 3rd MAP, somaclone CHP 118 recorded the highest value (61.42) for total number of leaves per plant and minimum by CHP 282 (34.17). During 4th MAP, somaclone CHP 118 recorded highest number of total leaves per plant with a value of 69.82 and was on par with SE 8626 (68.33), SE 8642 (63.89), C 8632 (62.01) and CHP 282 (59.72). During 5th MAP, somaclone CHP 118 recorded highest value (93.67) followed by C 8632 (91.87), SE 8626 (86.10), SE 8683 (85.67), SE 8642 (85.03) and CHP 282 (84.67). At 6 MAP, total number of leaves per plant ranged from 86.44 (CHP 99) and 117.33 (CHP 118). CHP 118 recorded maximum number of leaves per plant (117.33) and was on par with SE 8626 (108.33), SE 8642 (108.11) and C 8632 (107.33). Number of leaves increased with growth stages upto 6 month of planting and later decreased.

4.1.1.6 Leaf area

The leaf area of different somaclones was recorded from two months after planting (MAP) and significant difference was found among the somaclones for this character from 2nd to 6th MAP (Table 6). At 2 MAP the highest value (61.86 cm^2) for leaf area was recorded by the somaclone CHP 118 and lowest (25.59 cm^2) for the somaclone SE 8683. Leaf area increased with age of the plant. During 3rd MAP, the somaclone CHP 118 registered the highest value (65.42 cm^2) and was on par with CHP 282 (63.69 cm^2). During 4th MAP, the somaclone CHP 118 recorded the highest value (72.22 cm^2) and was on par with C 8632 (70.48 cm^2). At 5th and 6th MAP, leaf area of the somaclones exhibited a declining trend and during these periods, C8632 recorded the highest values (62.12 and 49.72 cm^2 respectively) for leaf area.

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Table 5. Total number of leaves per plant at different growth stages

Genotypes	Total number of leaves per plant				
	2 MAP	3 MAP	4 MAP	5 MAP	6 MAP
SE 8626	21.77	50.84	68.33	86.10	108.33
SE 8683	18.76	45.50	53.76	85.67	104.00
C 8626	10.97	40.36	52.87	78.00	100.77
CHP 118	21.03	61.42	69.82	93.66	117.33
C 78284	12.96	40.39	49.80	71.33	100.97
SE 86102	13.96	41.44	58.76	80.00	98.84
SE 8642	20.86	50.27	63.89	85.03	108.11
C 8632	19.06	41.76	62.01	91.87	107.33
CHP 99	16.13	41.67	58.17	80.80	86.44
CHP282	17.66	34.17	59.72	84.67	104.67
Rio-de-Janeiro	10.60	36.33	58.76	72.37	95.167
Himachal	12.30	36.20	53.76	78.67	95.20
Aswathy	13.53	42.50	59.76	73.46	97.69
CD (0.05)	3.60	6.76	10.48	12.32	10.85

Table 6. Leaf area of ginger genotypes at different growth stages

Genotypes	Leaf area (cm^2)				
	2 MAP	3 MAP	4 MAP	5 MAP	6MAP
SE 8626	48.33	53.23	67.31	55.14	37.97
SE 8683	25.59	43.72	53.63	48.08	34.61
C 8626	28.72	37.39	58.51	43.60	39.69
CHP 118	61.86	65.42	72.22	51.74	39.00
C 78284	41.61	53.89	58.02	50.63	45.80
SE 86102	41.25	55.42	51.10	42.09	35.21
SE 8642	42.66	46.14	65.35	58.46	49.13
C 8632	48.57	53.83	70.48	62.12	49.72
CHP 99	33.64	50.74	52.48	37.43	46.40
CHP282	58.32	63.69	60.37	52.56	37.92
Rio-de-Janeiro	35.23	51.31	57.85	41.38	45.09
Himachal	34.44	59.45	56.25	41.88	37.04
Aswathy	39.43	45.93	60.12	43.25	33.83
CD (0.05)	0.13	2.96	1.75	2.96	2.42

MAP- Months After Planting

4.1.1.7 Rhizome characters

a. Number of rhizomes

The data presented in Table 7 shows the number of primary (1^0), secondary (2^0), tertiary (3^0) and quaternary (4^0) rhizomes of different somaclones recorded at full maturity stage of ginger. There was significant difference among the somaclones for the number of primary rhizomes and the highest value (4.83) was recorded by the CHP 118 and was on par with SE 8626 (4.33) and C 8632 (4.08). The lowest number of primary rhizome was for CHP 99 (2.52). The number of secondary rhizomes was also found maximum for CHP 118 with a value of 10.33 and was on par with SE 8626 (10.06) and C 8632 (10.01). The lowest number of secondary rhizomes was for somaclones CHP 99 and CHP 282 with a value of 6.00. The number of tertiary rhizomes was also found maximum for CHP 118 (17.00) and lowest was for the check variety Himachal (7.67). The maximum number of quaternary rhizomes (12.67) was recorded for the somaclone SE 8626 and was on par with CHP 118 (10.67) and SE 8683 (9.33) and lowest value (3.00) was for CHP 99 and C 8626.

b. Weight of rhizomes

The weight of mother rhizome varied from 5.60 to 11.00 grams among the somaclones and check varieties (Table 7). The highest value (11.00 g) was for the somaclone SE 8642, on par with CHP 118 (10.67g) and the lowest mother rhizome weight (5.60 g) was recorded in Rio-de-Janeiro. The average weight of primary rhizome showed significant variation among the somaclones. The highest value for the weight of primary rhizome (15.73 g) was recorded for SE 8642 and was on par with SE 8626 (15.07 g), CHP 118 (14.80 g) and C 8632 (14.01 g) and the lowest value was for SE 86102 (8.10 g). The highest value (13.20 g) for secondary rhizome was recorded for SE 8626 followed by the somaclones SE 86 42 (12.33 g) and the lowest was for CHP 282 (6.33 g).

c. Length of rhizomes

The data on the average length of primary (1^0) and secondary (2^0) rhizomes are given in Table 8. The average length of primary rhizome was recorded highest in the somaclone CHP 118 (3.80 cm) followed by SE 8626 (3.67 cm), SE 8683

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Table 7. Number and weight of rhizomes in ginger genotypes

Genotypes	Number of rhizomes				Weight of rhizomes (g)		
	1^{o}	2^{o}	3^{o}	4^{o}	Mother	1^{o}	2^{o}
SE 8626	4.33	10.06	14.00	12.67	9.67	15.07	13.20
SE 8683	3.33	7.33	9.67	9.33	7.43	11.40	8.20
C 8626	3.33	6.33	13.00	3.00	8.10	10.47	7.47
CHP 118	4.83	10.33	17.00	10.67	10.67	14.80	11.21
C 78284	3.01	8.67	10.33	7.33	8.80	11.07	8.43
SE 86102	2.98	7.67	13.33	8.67	6.03	8.10	7.42
SE 8642	3.98	8.33	14.67	8.67	11.00	15.73	12.33
C 8632	4.08	10.01	14.00	5.00	9.23	14.01	10.40
CHP 99	2.52	6.00	11.00	3.00	7.90	11.13	7.10
CHP2 82	3.33	6.00	13.67	6.33	6.27	11.30	6.33
Rio-de-Janeiro	3.67	8.33	11.33	5.00	5.60	11.28	8.87
Himachal	3.33	8.67	7.67	3.33	7.83	10.43	9.10
Aswathy	3.42	8.67	12.33	7.33	7.80	11.43	8.17
CD (0.05)	0.75	1.22	3.22	3.46	0.52	1.25	1.08

Table 8. Length and girth of rhizomes in ginger genotypes

Genotypes	Length of rhizome (cm)		Internodal length of rhizome (cm)		Girth of rhizomes (cm)	
	1^{o}	2^{o}	1^{o}	2^{o}	1^{o}	2^{o}
SE 8626	3.67	3.57	1.17	1.03	9.20	7.73
SE 8683	3.43	3.23	0.70	0.60	8.20	8.20
C 8626	3.23	3.13	0.80	0.57	7.47	6.23
CHP 118	3.80	3.52	1.87	0.83	8.57	9.07
C 78284	3.15	3.07	0.83	0.67	7.10	5.87
SE 86102	2.97	2.13	0.77	0.63	8.37	5.67
SE 8642	3.23	2.73	0.87	0.60	9.07	6.37
C 8632	3.41	3.34	1.03	0.87	8.57	6.03
CHP 99	2.97	2.72	0.87	0.80	7.37	7.03
CHP 282	2.50	2.10	0.97	0.73	8.03	6.43
Rio-de-Janeiro	3.40	3.20	0.83	0.70	6.47	6.47
Himachal	3.33	3.07	0.73	0.67	7.40	6.50
Aswathy	3.27	3.07	0.70	0.73	7.00	7.47
CD (0.05)	0.39	0.35	0.08	0.22	0.69	0.42

MAP- Months After Planting

(3.43 cm) and C 8632 (3.41 cm) and lowest value (2.50 cm) was recorded by the somaclone CHP 282 (Table 8). The highest value for the length of secondary rhizome was recorded by SE 8626 (3.57 cm) followed by CHP 118 (3.52 cm) and C 8632 (3.34 cm) the lowest value (2.10 cm) by the somaclone CHP 282.

d. Internodal length of rhizomes

Internodal length of primary rhizomes recorded among the somaclones and check varieties ranged between 0.70 cm to 1.87 cm (Table 8). The highest value (1.87 cm) was recorded for the somaclone CHP 118 and the lowest value (0.70 cm) was recorded for the somaclone SE 86 83 and Aswathy. For the internodal length of secondary rhizomes, the highest value was recorded by the somaclone SE 86 26 (1.03 cm) followed by CHP 118 (0.83 cm) and C 8632 (0.87 cm) and the lowest value (0.57 cm) was for the somaclone C 8626.

e. Girth of rhizomes

Girth of primary rhizomes ranged from 6.47 to 9.20 cm (Table 8). The highest value was recorded in the somaclone SE 8626 (9.20 cm) followed by SE 8642 (9.07 cm), CHP 118 (8.57 cm) and C 8626 (8.57 cm) and the lowest value (6.47 cm) was registered in the control Rio-de-Janeiro. The girth of secondary rhizomes recorded ranged between 5.67 cm (SE 86102) to 9.07 cm (CHP 118).

f. Thickness of fingers

The thickness of primary (1^0) and secondary (2^0) rhizomes recorded varied among the somaclones (Table 9). The maximum thickness of primary finger (2.67 cm) was registered in the somaclone SE 86 26 followed by CHP 118 (2.63 cm) and CHP 282 (2.57 cm) whereas C 8626 recorded lowest value (2.07 cm). The thickness of secondary (2^0) finger was found to be maximum in the somaclone SE 8626 (2.53 cm) and the minimum in C 78 284 (1.77 cm).

g. Thickness of core

The core thickness of primary rhizome was found to be maximum in the somaclone SE 8626 (2.33 cm) and the minimum value (1.73 cm) was registered for the somaclone SE 86102. Secondary rhizome core thickness was found highest

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Table 9. Rhizome characters and yield of ginger genotypes

Genotypes	Thickness of finger (cm)		Thickness of core (cm)		Fresh yield / plant (g)	Fresh yield / plot (kg)	Fresh yield / ha (t)
	1°	2°	1°	2°			
SE 8626	2.67	2.53	2.33	2.03	266.67	8.54	34.16
SE 8683	2.20	1.97	2.00	1.87	145.33	4.65	18.60
C 8626	2.07	2.00	1.87	1.63	201.93	6.48	25.92
CHP 118	2.63	2.33	2.00	1.77	274.13	8.77	35.08
C 78284	2.10	1.77	1.77	1.57	209.67	6.51	26.04
SE 86102	2.13	2.20	1.73	1.60	176.47	5.65	22.60
SE 8642	2.43	2.20	1.73	1.57	251.67	8.06	32.24
C 8632	2.30	2.20	2.00	1.60	259.67	8.31	33.24
CHP 99	2.17	2.13	1.93	1.47	131.53	4.21	16.84
CHP 282	2.57	2.11	2.07	1.67	206.27	6.60	26.40
Rio-de-Janeiro	2.40	2.13	2.07	1.67	196.67	6.29	25.16
Himachal	2.40	1.87	1.97	1.47	187.73	6.01	24.04
Aswathy	2.41	2.13	2.07	1.47	201.20	6.43	25.72
CD (0.05)	0.15	0.16	0.26	0.13	29.71	1.05	1.80

Table 10. Driage and dry yield of ginger genotypes

Genotypes	Driage (%)	Dry yield/ plot (kg)	Dry yield/ha (t)
SE 8626	23.18	1.98	7.92
SE 8683	14.34	0.66	2.64
C 8626	15.14	0.98	3.92
CHP 118	19.71	1.73	6.92
C 78284	15.52	1.01	4.04
SE 86102	15.91	0.89	3.56
SE 8642	21.20	1.71	6.84
C 8632	17.91	1.49	5.96
CHP 99	15.43	0.65	2.60
CHP 282	13.56	0.89	3.56
Rio-de-Janeiro	15.23	0.96	3.84
Himachal	15.83	0.89	3.56
Aswathy	17.20	1.10	4.40
CD (0.05)	0.02	0.01	0.02

MAP- Months After Planting

in SE 8626 (2.03 cm) and minimum (1.47 cm) in somaclone CHP 99 and check varieties Himachal and Aswathy (Table 9).

4.1.1.8 Yield Characters

a. Fresh Yield

Significant difference was observed among somaclones and check varieties in the yield characters recorded at full maturity stage (Table 9). The highest fresh rhizome yield per plant (274.13 g) was recorded by somaclone CHP 118 followed by SE 8626 (266.67 g), C 8632 (259.67 g) and SE 8642 (251.67 g) after harvest. The highest yield per plot (8.77 kg) recorded by somaclone CHP 118 followed by SE 8626 (8.54 kg), C 8632 (8.31 kg) and SE 8642 (8.06 kg). The fresh rhizome yield per hectare was maximum for the somaclone CHP 118 (35.08 t) followed by SE 8626 (34.16 t), C 8632 (33.24 t) and SE 8642 (32.24 t). The three check varieties namely Rio- de-Janeiro, Himachal and Aswathy recorded an average yield of 24-25 tonnes from a hectare in this study.

b. ***Dry Yield***

Dry recovery or driage of the rhizomes ranged between 13.56 % to 23.18 % (Table 10). The highest dry recovery was recorded by the somaclone SE 8626 (23.18 %) followed by SE 8642 (21.20%) and the lowest value (13.56 %) was registered in CHP 282. Dry yield per plot was found highest for the somaclone SE 8626 (1.98 kg) followed by CHP 118 (1.73 kg), SE 8642 (1.71 kg) and C 8632 (1.49 kg). The somaclone SE 8626 registered highest value (7.92 t) for dry yield per hectare followed by CHP 118 (6.92 t), SE 8642 (6.84 t) and C 8632 (5.96 t).

4.1.1.9 Quality parameters

a. Volatile oil

The volatile oil content of two somaclones (SE 8626 and CHP 118) and two check varieties (Rio- de-Janeiro and Himachal) was more than 3 %. Among the somaclones, CHP 118 recorded the highest value (3.80 %) for volatile oil content followed by SE 8626 (3.30 %) and in check varieties higher values were

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observed in Rio- de-Janeiro (3.02 %) and Himachal (3.01 %). Content of volatile oil was very low (2.10 %) in SE 8683 and C 8626 (Table 11).

b. Oleoresin

Oleoresin percentage ranged from 4.02 % (C 8626) to 6.58 % (Rio- de-Janeiro) as observed in Table 11. All the three check varieties were rich in oleoresin and the content was more than 6 %. Among the somaclones, higher content (> 6%) of oleoresin was observed in SE 8626 (6.50 %), CHP 118 (6.19 %), C 78284 (6.12 %) and CHP 282 (6.23 %), whereas SE 8683 (4. 23 %) and C 8626 (4.02 %) recorded lowest content of oleoresin.

c. Crude fibre

Crude fibre content varied from 2.13 % to 4.03 % among the somaclones at five month maturity (Table 11). The maximum crude fiber content (4.03 %) was registered by the somaclone SE 8626 and the lowest value (2.13 %) was recorded by the somaclone C 8626. SE 86102, C 8632, CHP 99 and Rio-de-Janeiro recorded a fibre content of 3 % at 5 month stage. At seven month maturity, the highest crude fibre content (4.89 %) was registered in the somaclone SE 8626 and the lowest value (3.00 %) was for the somaclones SE 8642 and CHP 282. CHP 118, SE 86102 and Himachal recorded a fibre content of 4 % at 7 month stage.

d. Starch

Starch content showed significant variation among the somaclones (Table 11). The highest starch content was observed in the check variety Aswathy with 45.30 % and the lowest was for the somaclone C 78284 at seven month maturity. The somaclones SE 8626 and CHP 99 recorded starch content more than 40 % at this growth stage compared to others.

4.1.1.10 Chemoprofiling of ginger genotype by HPLC

a. Gingerol content

The somaclones showed significant variation among the content of gingerols (Table 12). (6)- Gingerol was found highest in Rio-de-Janeiro (1.20 %)

Table 11. Quality parameters of ginger genotypes

Genotypes	Volatile oil (%)	Oleoresin (%)	Crude fibre (%)		Starch (%)
			5 month stage	7 month stage	
SE 8626	3.30	6.50	4.03	4.89	42.50
SE 8683	2.10	4.23	2.20	3.53	30.10
C 8626	2.10	4.02	2.13	3.50	32.30
CHP 118	3.80	6.19	2.53	4.00	35.20
C 78284	2.90	6.21	2.47	3.53	28.50
SE 86102	2.60	5.59	3.00	4.00	38.70
SE 8642	2.58	5.22	2.31	3.00	37.40
C 8632	2.70	5.61	3.00	3.50	32.70
CHP 99	2.50	5.04	3.00	3.47	40.00
CHP282	2.70	6.23	2.50	3.00	39.10
Rio-de-Janeiro	3.02	6.58	3.03	3.70	35.00
Himachal	3.01	6.37	2.60	4.00	39.40
Aswathy	2.90	6.23	2.52	3.53	45.30
CD (0.05)	**0.04**	**0.07**	**0.19**	**0.22**	**0.17**

Table 12. Gingerol and shogaol content of ginger genotypes

Genotypes	6-Gingerol (%)	8-Gingerol (%)	10-Gingerol (%)	Total Gingerol (%)	Total shogoal (%)	Total Gingerol + Shogaol (%)
SE 8626	0.05	0.01	0.01	0.07	0.01	0.08
SE 8683	0.06	0.01	0.01	0.08	0.01	0.09
C 8626	0.05	0.01	0.01	0.07	0.01	0.08
CHP 118	0.03	0.01	0.01	0.05	0.01	0.06
C 78284	0.10	0.01	0.01	0.12	0.01	0.13
SE 86102	0.12	0.01	0.01	0.14	0.03	0.17
SE 8642	0.10	0.04	0.02	0.16	0.10	0.26
C 8632	0.12	0.01	0.01	0.14	0.01	0.15
CHP 99	0.12	0.01	0.01	0.14	0.02	0.16
CHP282	0.98	0.09	0.10	1.17	0.16	1.33
Rio-de-Janeiro	1.20	0.14	0.14	1.48	0.11	1.59
Himachal	0.67	0.08	0.10	0.85	0.07	0.92
Aswathy	1.12	0.16	0.07	1.35	0.09	1.44
CD (0.05)	**0.19**	**0.04**	**0.05**	**0.22**	**0.03**	**1.02**

and Aswathy (1.12 %). Similarly (8) - Gingerol was also observed maximum in Rio-de-Janeiro (0.14 %) and Aswathy (0.16 %). Higher values (> 0.10 %) for (10)- Gingerol was recorded in CHP 282 (0.10 %) and Himachal (0.10%) and Rio-de-Janeiro (0.14 %).

b. Shogaol content

The total shogaol content was registered highest in CHP 282 (0.16 %) followed by Rio-de-Janeiro (0.11 %) and SE 8642 (0.10 %). (Table 12). The check varieties Himachal and Aswathy yielded higher total shogaol than other somaclones except SE 8642 and CHP 282.

1.1.11 Physiological characters

Physiological characters *viz.,* chlorophyll index, photosynthetic rate, transpiration rate and stomatal conductance were measured at 6 month stage and presented in table 13.

a. Chlorophyll Index

The chlorophyll index of somaclones ranged from 36.02 to 45.25 with highest in Himachal (45.25) and the lowest was for the somaclone C 8626 (36.02) (Table 13). Chorophyll index values were higher (> 40) in seven somaclones namely SE 8683 (41.30), CHP 118 (41.19), SE 8642 (41.83), CHP 99(43.58), CHP 282 (42.65), Rio-de-Janeiro (42.64) and Himachal (45.25).

b. Photosynthetic Rate

The photosynthetic rate was recorded maximum for the somaclone SE 8642 (20.13 μmol $m^{-2}sec^{-1}$) and the lowest was for Rio-de-Janeiro (11.00 μmol $m^{-2}sec^{-1}$) at six month maturity (Table 13).

c. Transpiration Rate

The transpiration rate was recorded maximum for the somaclone SE 8642 (1.56 μmol $m^{-2}sec^{-1}$) and the lowest was for CHP 99 (0.63 μmol $m^{-2}sec^{-1}$) at six month maturity (Table 13).

Table 13. Physiological parameters of ginger genotypes at 6 MAP

Genotypes	Chlorophyll Index	Photosynthetic rate (μmol $m^{-2}sec^{-1}$)	Transpiration rate (μmol $m^{-2}sec^{-1}$)	Stomatal conductance (m μmol $m^{-2}sec^{-1}$)
SE 8626	39.97	14.63	0.91	0.02
SE 8683	41.30	11.87	0.94	0.02
C 8626	36.02	11.73	0.93	0.03
CHP 118	41.19	18.80	0.94	0.02
C 78284	37.48	11.90	0.77	0.03
SE 86102	38.65	11.21	0.77	0.03
SE 8642	41.83	20.13	1.56	0.05
C 8632	37.06	17.47	0.93	0.03
CHP 99	43.58	18.75	0.63	0.02
CHP282	42.65	12.37	0.74	0.03
Rio-de-Janeiro	42.64	11.00	0.74	0.03
Himachal	45.25	11.97	0.71	0.05
Aswathy	38.87	12.10	0.77	0.02
CD (0.05)	2.58	0.08	0.01	NS

Table 14. Shoot borer and rhizome rot incidence in genotypes at 6 MAP

Genotypes	Shoot borer (%)	Rhizome rot (%)
SE 8626	4.79	4.79
SE 8683	18.7	3.13
C 8626	9.87	4.79
CHP 118	6.25	3.13
C 78284	21.88	9.87
SE 86102	6.25	8.33
SE 8642	7.21	4.17
C 8632	5.21	3.13
CHP 99	6.25	5.21
CHP282	3.13	7.21
Rio-de-Janeiro	18.75	9.37
Himachal	9.37	7.21
Aswathy	28.13	3.13
CD (0.05)	3.21	1.01

d. Stomatal conductance

No significant difference was noticed for this character among the genotypes. However, the stomatal conductance was higher in the somaclone SE 8642 and Himachal (0.05 m µmol $m^{-2}sec^{-1}$) and lower in SE 8626, SE 8683, CHP 118, CHP 99 and Aswathy (0.02 m µmol $m^{-2}sec^{-1}$) at six month maturity (Table 13).

4.1.1.11 Pest and disease incidence

Incidence of the major pest, "shoot borer" attack in ginger was observed during the 6 MAP (Table 14 and Plate 10). Six somaclone were found to have minor attack namely CHP 282 (3.13 %), SE 8626 (4.79 %), C 8632 (5.21 %) and CHP 118, SE 86102 and CHP 99 with 6.25 % incidence compared to other somaclones and check varieties. Highest incidence was observed in check variety Aswathy (28.13 %) at this stage.

Rhizome rot incidence was also recorded at 6 MAP (Table 14 and Plate 10). Somaclones SE 8683, CHP 118, C 8632 and Aswathy recorded minor incidence with a value of 3.13 %. Other somaclones such as SE 8642 (4.17 %), SE 8626 (4.79 %) and C 8626 (4.79 %) recorded incidence less than 5 % compared to others. C 78284 recorded the highest incidence of 9.87 %.

4.2 PERFORMANCE OF GINGER GENOTYPES UNDER DIFFERENT GROWING CONDITIONS

Four somaclones (SE 8681, SE 8640, SE 86131 and SEHP 9) along with the KAU released variety Aswathy is grown both in open field and rain shelter and observations were recorded to study there performance.

4.2.1 Morphological Characters

Morphological characters and yield attributes of four somaclones along with one check variety (Aswathy) were recorded for a period of six months from planting. Morphological characters recorded include number of days for sprouting, plant height, number of tillers per plant, number of leaves per shoot, total number of leaves per plant and leaf area.

4.2.1.1 Number of days for sprouting

There was significant difference among the somaclones on the number of days for sprouting (Table 15). The minimum number of days for sprouting was recorded by Aswathy (13.67 days) under open field condition and was on par with somaclone SEHP 9 (14.51 days), whereas somaclone SE 8681 recorded the highest number of days for sprouting (16.25 days) in open field. Under rain shelter condition, the somaclone SE 8640 (11.50 days) showed early sprouting compared to other somaclones and check variety. Mean values showed earliness in sprouting under rain shelter condition (13.74 days) compared to open field (15.13 days). The check variety Aswathy recorded least number of days for sprouting (13.43 days) followed by SE 8640 (13.50 days) and SEHP 9 (13.75 days) irrespective of the growing conditions as revealed from mean values. The somaclone SE 86131 and SE 8681 showed delayed sprouting compared to others with a value of 15.75 days and 15.74 days respectively (Table 15).

4.2.1.2 Plant height

Plant height was recorded at monthly intervals and the data is furnished in Table 16, Plate 7 & 8. Somaclones varied among themselves for plant height under both the growing conditions. Significant difference was observed among the somaclones in open field. At 2 month stage, the plant height ranged from 26.64 cm (SE 8681) to 30.78 cm (SE 8640) which increased and ranged between 33.26 cm (Aswathy) and 55.56 cm (SE 8640) at 3 month stage under open field (Table 16a.). In rain shelter, plant height was higher in all genotypes than in open field which ranged from 26.63 cm (Aswathy) and 35.45 cm in SE 8640 at 2 month stage and from 45.04 (Aswathy) to 52.03 cm (SE 8640) at 3 month stage. The somaclone SE 8640 registered highest plant height (60.09 cm) at 4 MAP, which was on par with SEHP 9 (55.46 cm) under open field condition, whereas in rain shelter, SE 8640 showed its superiority with highest plant height of 69. 81cm than

Open field

Rain shelter

Plate 7. Crop at 4 months stage

Table 15. Effect of growing conditions on days to sprout in ginger genotypes

Genotypes	Number of days for sprouting		Mean
	Open field	Rain shelter	
SE 8681	16.25	15.25	15.75
SE 8640	15.49	11.50	13.50
SE 86131	15.75	15.75	15.75
SEHP 9	14.51	13.00	13.75
Aswathy	13.67	13.20	13.43
CD (0.05)	1.45	1.27	
Mean	15.13	13.74	
CD (A)	0.58		
CD (B)	0.90		
CD (A x B)	1.28		

A- Growing conditions and B- Genotypes

Table 16a. Effect of growing conditions on plant height of ginger genotypes at 2 & 3 MAP

Genotypes	Plant height (cm) 2 MAP		Plant height (cm) 3 MAP	
	Open field	Rain shelter	Open field	Rain shelter
SE 8681	26.64	32.97	35.02	48.65
SE 8640	30.78	35.45	55.56	52.03
SE 86131	27.23	30.97	34.06	46.76
SEHP 9	29.28	34.31	41.86	49.10
Aswathy	28.37	26.63	33.26	45.04
CD (0.05)	**NS**	**2.26**	**4.55**	**3.46**

Table 16b. Effect of growing conditions on plant height in ginger genotypes at 4,5 & 6 MAP

Genotypes	Plant height (cm) 4 MAP		Plant height (cm) 5 MAP		Plant height (cm) 6 MAP	
	Open field	Rain shelter	Open field	Rain shelter	Open field	Rain shelter
SE 8681	52.17	61.02	67.78	77.28	92.28	83.84
SE 8640	60.09	69.81	74.17	81.60	92.60	87.84
SE 86131	51.65	60.56	65.60	75.31	86.32	83.81
SEHP 9	55.46	64.85	73.35	82.16	89.72	88.78
Aswathy	52.45	60.61	61.40	64.89	79.83	72.55
CD (0.05)	**5.32**	**3.81**	**3.25**	**5.75**	**3.55**	**2.85**

others. The lowest height under rain shelter was for SE 86131 (60.56 cm). At 5 MAP, SE 8640 was taller under both the growing conditions with a plant height of 74.17 cm (open field) and 81.60 cm (rain shelter) followed by SEHP 9 (73.35 cm in open and 82.16 cm in rain shelter) (Table 16b.).

During 6 months after planting, plant height among the somaclones ranged from 79.83 to 92.60 cm under open field condition. The maximum plant height was recorded by SE 8640 (92.60 cm), SE 8681 (92.28 cm) and SEHP 9 (89.72 cm) and the lowest was for Aswathy (79.83 cm) in open field. Under rain shelter condition, plant height ranged from 72.55 to 88.78 cm. The somaclone, SEHP 9 recorded maximum plant height (88.78 cm) followed by SE 8640 (87.84 cm) and the lowest plant height was recorded in Aswathy (72.55 cm) (Table 16c.).

4.1.1.3 Number of tillers per plant

Mean values of the number of tillers per plant are furnished in the Table 17. There was significant difference in the number of tillers produced by the somaclones under different growing conditions. The numbers of tillers were less under rain shelter condition in all growth stages. At 2 MAP, number of tillers ranged from 2.50 (Aswathy) to 4.53 (SEHP 9) under open field condition and under rain shelter, tiller number ranged from 1.34 (Aswathy) to 2.62 (SE 8640) (Table 17a.). Later number of tillers increased with age of the plant and at 3 month stage it varied from 5.38 (Aswthy) to 7.24 (SE 8640) in open field condition and from 2.12 (Aswathy) to 3.58 (SE 8640) in rain shelter. At 4 month stage, SEHP 9 registered the highest value (10.52) followed by SE 8681 (10.01) under open field condition and the lowest was for the check variety Aswathy (7.67). In rain shelter, SEHP 9 (4.25) and SE 8681 (4.01) registered the maximum number of tillers (Table 17b.).

During 5 MAP, the tiller number ranged from 10.60 (Aswathy) to 13.45 (SEHP 9) under open field and from 4.21 (Aswathy) to 6.64 (SE 8640) in rain shelter. At 6 MAP, the number of tillers produced by ginger somaclones under open field condition ranged from 14.69 to 17.09. The somaclone SEHP 9 recorded the maximum number of tillers (17.09) followed by SE 8681 (15.67) and the

Open field

Rain shelter

Plate 8. Crop at 6 months stage

Table 16c. Mean plant height in ginger genotypes at 4 & 6 MAP

Genotypes	Plant height (cm) 4 MAP		Mean	Plant height (cm) 6 MAP		Mean
	Open field	Rain shelter		Open field	Rain shelter	
SE 8681	52.17	61.02	56.59	92.28	83.84	88.06
SE 8640	60.09	69.81	64.95	92.60	87.84	90.22
SE 86131	51.65	60.56	56.11	86.32	83.81	85.07
SEHP 9	55.46	64.85	60.15	89.72	88.78	89.25
Aswathy	52.45	60.61	60.53	79.83	72.55	76.19
CD (0.05)	5.32	3.81		3.55	2.85	
Mean	54.36	63.37		88.15	83.36	
CD (A)	1.91			1.33		
CD (B)	3.02			2.10		
CD (A x B)	NS			2.97		

A- Growing conditions and B- Genotypes

Table 17a. Effect of growing conditions on tillers in ginger genotypes at 2 & 3 MAP

Genotypes	Number of tillers 2 MAP		Number of tillers 3 MAP	
	Open field	Rain shelter	Open field	Rain shelter
SE 8681	3.81	1.70	6.36	3.16
SE 8640	3.01	2.62	7.24	3.58
SE 86131	3.05	1.56	6.25	2.61
SEHP 9	4.53	1.91	7.15	3.35
Aswathy	2.50	1.34	5.38	2.12
CD (0.05)	**0.44**	**0.40**	**0.66**	**0.57**

Table 17b. Effect of growing conditions on tillers in ginger genotypes at 4, 5 & 6 MAP

Genotypes	Number of tillers 4 MAP		Number of tillers 5 MAP		Number of tillers 6MAP	
	Open field	Rain shelter	Open field	Rain shelter	Open field	Rain shelter
SE 8681	10.01	4.01	11.25	4.82	15.67	7.20
SE 8640	9.12	3.92	12.83	6.64	14.93	6.90
SE 86131	8.92	3.56	10.74	4.53	14.92	6.70
SEHP 9	10.52	4.25	13.45	5.33	17.09	7.80
Aswathy	7.67	2.92	10.60	4.21	14.69	6.10
CD (0.05)	**0.38**	**0.46**	**1.85**	**0.90**	**1.54**	**1.02**

Table 17c. Mean number of tillers of ginger genotypes at 4 & 6 MAP

Genotypes	Number of tillers 4 MAP		Mean	Number of tillers 6 MAP		Mean
	Open field	Rain shelter		Open field	Rain shelter	
SE 8681	10.01	4.01	7.01	15.67	7.20	11.44
SE 8640	9.12	3.92	6.52	14.69	6.90	10.80
SE 86131	8.92	3.56	6.24	14.92	6.70	10.81
SEHP 9	10.52	4.25	7.38	17.10	7.80	12.45
Aswathy	7.67	2.92	5.29	14.93	6.10	10.51
CD (0.05)	**0.38**	**0.46**		**1.54**	**1.02**	
Mean	9.25	3.73		15.46	6.94	
CD (A)	0.22			0.64		
CD (B)	0.35			1.01		
CB (A x B)	0.50			NS		

Table 18a. Effect of growing conditions on number of leaves /shoot at 2&3 MAP

Genotypes	No. of leaves/ shoot 2 MAP		No. of leaves/ shoot 3 MAP	
	Open field	Rain shelter	Open field	Rain shelter
SE 8681	8.56	5.30	12.50	7.03
SE 8640	8.60	6.38	13.32	8.47
SE 86131	8.53	4.60	12.33	5.77
SEHP 9	10.68	4.89	13.13	6.07
Aswathy	7.21	4.24	11.25	5.49
CD (0.05)	**0.74**	**0.78**	**NS**	**1.34**

Table 18b. Effect of growing conditions on number of leaves /shoot at 4,5&6 MAP

Genotypes	No. of leaves/ shoot					
	4 MAP		5 MAP		6 MAP	
	Open field	Rain shelter	Open field	Rain shelter	Open field	Rain shelter
SE 8681	12.30	9.82	16.51	13.63	19.20	14.48
SE 8640	14.10	12.10	17.71	17.62	23.10	20.23
SE 86131	12.11	8.23	15.61	12.30	18.27	13.60
SEHP 9	13.20	9.12	16.01	13.72	21.81	14.51
Aswathy	11.22	8.10	15.08	11.10	20.20	12.45
CD (0.05)	**1.69**	**1.40**	**1.43**	**2.19**	**0.95**	**1.03**

lowest was for Aswathy (14.69). The somaclone, SEHP 9 also recorded highest value for number of tillers per plant (7.80) under rain shelter condition and was on par with SE 8681 (7.20), SE 8640 (6.90) and SE 86131 (6.70). The check variety Aswathy recorded the lowest value of 6.10 (Table 17c.).

4.1.1.4 Number of leaves per shoot

The number of leaves per shoot was recorded at monthly intervals upto 6 month stage and the data is furnished in Table 18. Significant difference was observed between somaclones in the number of leaves per shoot raised under two growing conditions. Number of leaves per shoot was higher in open field condition ranging from 7.21 (Aswathy) to 10.68 (SEHP 9) at 2 month stage, whereas in rain shelter, leaf number ranged from 4.24 (Aswathy) to 6.38 (SE 8640). At 3 month growth stage, number of leaves did not differ significantly among genotypes under open field condition and in rain shelter (Table 18a.). Significant difference was noticed with values ranging from 5.49 (Aswathy) to 8.47 (SE 8640). At 4 MAP, the somaclone SE 8640 recorded the highest value (14.10) for number of leaves per shoot followed by SEHP 9 (13.20) and SE 8681 (12.30) and the lowest value (11.25) was for the check variety Aswathy, under open field. In rain shelter condition, the somaclone SE 8640 (12.10) recorded the maximum value and again the lowest was in Aswathy (8.10). During 5 MAP, SE 8640 recorded the highest value (17.72) followed by SE 8681 (16.51) and the lowest was for Aswathy (15.08). In rain shelter, the highest number of leaves per shoot (17.11) was registered in the somaclone SE 8640 and the lowest was for SE 86131(`12.30) and Aswathy (11.10) (Table 18b.).

During 6 MAP, the somaclone SE 8640 recorded highest number of leaves per shoot under open field and rain shelter conditions, with a value of 23.10 and 20.23 respectively. The lowest value for number of leaves per shoot under open field was registered in SE 8681 (19.20) and SE 86 131 (18.27) and in rain shelter lowest number of leaves per plant was for Aswathy (12.45).

Table 18c. Mean number of leaves /shoot in ginger genotypes

Genotypes	Number of leaves /shoot 4 MAP		Mean	Number of leaves /shoot 6 MAP		Mean
	Open field	Rain shelter		Open field	Rain shelter	
SE 8681	12.30	9.82	11.06	19.20	14.48	16.84
SE 8640	14.10	12.10	13.10	23.10	20.23	21.65
SE 86131	12.11	8.23	10.17	18.27	13.60	15.93
SEHP 9	13.20	9.12	11.16	21.81	14.51	18.16
Aswathy	11.22	8.10	9.66	20.20	12.45	16.32
CD (0.05)	**1.69**	**1.40**		**0.95**	**1.03**	
Mean	12.58	9.47		20.52	15.05	
CD (A)	0.64			0.46		
CD (B)	1.01			0.73		
CB (A x B)	NS			1.03		

Table 19a. Effect of growing conditions on total number of leaves /shoot

Genotypes	Total no. of leaves/ plant 2 MAP		Total no. of leaves/ plant 3 MAP	
	Open field	Rain shelter	Open field	Rain shelter
SE 8681	15.35	7.97	33.90	25.25
SE 8640	12.31	9.30	34.55	28.50
SE 86131	11.56	7.87	33.25	23.84
SEHP 9	13.66	9.97	37.25	27.83
Aswathy	10.50	6.00	26.83	20.10
CD (0.05)	**2.69**	**2.29**	**NS**	**4.19**

Table 19b. Effect of growing conditions on total number of leaves /shoot of ginger genotypes at 4, 5 & 6 MAP

Genotypes	Total no. of leaves/ plant					
	4 MAP		5 MAP		6 MAP	
	Open field	Rain shelter	Open field	Rain shelter	Open field	Rain shelter
SE 8681	66.56	33.15	75.35	48.82	81.29	77.75
SE 8640	67.58	36.43	72.71	52.86	87.00	82.25
SE 86131	65.00	32.63	68.06	36.86	78.24	45.10
SEHP 9	70.26	39.30	76.14	59.05	87.47	78.77
Aswathy	52.31	30.25	66.04	45.10	73.81	36.86
CD (0.05)	**5.26**	**5.87**	**3.42**	**7.10**	**2.83**	**7.10**

4.2.1.5 Total number of leaves per plant

Table 19 shows the total number of leaves per plant recorded in different somaclones during the growing period and found significant difference for this character. Total number of leaves per plant during the 2 month stage ranged from 10.50 to 15.35 under open field condition. The somaclone SE 8681 registered the highest value (15.35) and it was on par with SEHP 9 (13.66). The lowest value was recorded in the check variety Aswathy (10.50).In rain shelter, the highest value (9.97) was recorded by the SEHP 9 followed by SE 8640 (9.30), SE 8681 (7.97) and SE 86131(7.87) and the lowest (6.00) for Aswathy (Table 19a.).

During 3 MAP, no significant differences on the total number of leaves per plant among somaclones were observed under open field condition. However in rain shelter, the total number of leaves per plant had significant difference among the ginger somaclones. The values ranged from 20.10 (Aswathy) to 28.50 (SE 8640).

At 4 MAP, SEHP 9 recorded the highest value for total number of leaves per plant (70.26) which was on par with SE 8640 (67.58) and SE 8681 (66.56) under open field condition. The lowest value was registered in Aswathy (52.31). In rain shelter, SEHP 9 recorded the maximum number of leaves per plant (39.30) followed by SE 8640 (36.43) and the lowest value were observed in Aswathy (30.25).

During 5 MAP, under open field condition, the somaclone SEHP 9 registered superiorly higher number of leaves per plant (76.14) which was on par to SE 8681 (75.35) and the lowest value was for SE 86131 (68.06) and Aswathy (66.04). In rain shelter, SEHP 9 recorded the highest number of leaves per plant (59.05) followed by SE 8640 (52.86) and the lowest were for Aswathy (45.10) (Table 19b.).

During 6 MAP, the somaclone, SEHP 9 recorded maximum number of leaves per plant (87.47) followed by SE 8640 (87.00) under open field condition and the lowest value was for Aswathy (73.14). The somaclone SE 8640 recorded the highest value for total number of leaves per plant (82.25) under rain shelter condition which was on par with SEHP 9 (78.77) and SE 8681 (77.75). The lowest was for the check variety Aswathy (36.86).

4.2.1.6 Leaf area

Leaf area of ginger somaclones grown under different growing conditions at different growth stages are presented in Table 20. In all stages of growth, leaf area was found higher in open field in all genotypes when compared to rain shelter cultivation.

At 2 MAP, the leaf area of somaclones ranged from 36.00 to 49.36 cm^2. SE 86131 recorded the maximum leaf area of 49.36cm^2 under open field condition which was on par with SEHP 9 (47.18 cm^2) and the lowest value was for Aswathy with 36.00 cm^2. In rain shelter, SE 8640 registered the highest value (39.59 cm2) followed by SEHP 9 (38.90 cm^2). During 3 MAP, The somaclone SE 8640 recorded the maximum value of 51.09 cm^2 and the lowest by Aswathy (40.10 cm^2) under open field condition. In rain shelter, SE 8640 registered the highest leaf area (43.04 cm^2) among the somaclones which was on par with SEHP 9 (40.95 cm^2) and the check variety recorded the lowest leaf area of 33.66 cm^2 (Table 20a.).

At 4 month stage also, leaf area varied significantly under both the growing conditions and SE 86131 recorded the highest leaf area of 58.93 cm^2 under open condition and the lowest was recorded by Aswathy (49.08 cm^2). In rain shelter, leaf area ranged from 37.51 cm^2 (SE 8681) to 50.41 cm^2 (SEHP 9).

During 5 MAP, SE 8640 and SEHP 9 recorded the highest leaf area (67.63 cm^2 and 66.81 cm^2 respectively) and the lowest was for Aswathy (50.28 cm^2) under open field. In rain shelter, SEHP 9 recorded the highest leaf area of 61.56 cm^2 and the lowest was for SE 86131 (47.98 cm^2) and Aswathy (46.22 cm^2) (Table 20b.).

Leaf area was found to be the highest for the somaclone SEHP 9(35.82 cm^2) under open field condition and the lowest was for SE 86131 (24.03 cm^2) at 6

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Table 20a. Effect of growing conditions on leaf area (cm^2) of ginger genotypes

Genotypes	Leaf area (2 MAP)		Leaf area (3 MAP)	
	Open field	Rain shelter	Open field	Rain shelter
SE 8681	43.30	38.67	48.95	40.66
SE 8640	43.73	39.59	51.09	43.04
SE 86131	49.36	35.79	48.83	39.98
SEHP 9	47.18	38.90	48.18	40.95
Aswathy	36.00	29.30	40.10	33.66
CD (0.05)	**2.76**	**1.72**	**1.79**	**2.30**

Table 20b. Effect of growing conditions on leaf area (cm^2) of ginger genotypes

Genotypes	Leaf area (4 MAP)		Leaf area (5MAP)		Leaf area (6MAP)	
	Open field	Rain shelter	Open field	Rain shelter	Open field	Rain shelter
SE 8681	55.81	37.50	55.53	50.05	33.00	31.79
SE 8640	57.86	41.94	67.63	55.34	31.23	27.15
SE 86131	58.93	45.81	53.39	47.98	24.03	21.82
SEHP 9	55.18	50.41	66.81	61.56	35.82	24.06
Aswathy	49.08	43.65	50.28	46.22	35.11	30.18
CD (0.05)	**0.13**	**0.14**	**2.48**	**2.99**	**0.20**	**0.25**

Table 21a. Effect of growing conditions on yield of ginger genotypes

Genotypes	Fresh yield /plant (g)		Fresh yield /plot (kg)		Fresh yield / ha (t)	
	Open field	Rain shelter	Open field	Rain shelter	Open field	Rain shelter
SE 8681	223.13	160.00	7.14	5.12	28.56	20.48
SE 8640	213.13	197.19	6.82	6.31	27.28	25.24
SE 86131	183.44	154.38	5.87	4.94	23.48	19.74
SEHP 9	253.75	157.81	8.12	5.05	32.48	20.20
Aswathy	185.31	155.31	5.93	4.97	23.72	19.88
CD (0.05)	**3.94**	**1.54**	**1.58**	**0.74**	**2.13**	**1.87**

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MAP. In rain shelter, SE 8681 recorded the highest leaf area (31.79 cm^2) and the lowest was for SE 86131 (21.87 cm^2).

4.2.2 Rhizome characters and yield

a. Number and weight of rhizomes

Numbers of primary of secondary, tertiary and quaternary rhizomes of the somaclones grown under different growing conditions varied significantly and are showed in the Table 21b. Number of primary rhizome under open field condition varied from 3.63 to 5.48 with highest in the somaclone SEHP 9 (5.48) which was on par with SE 8681 (5.13). The lowest value was for the check variety Aswathy (3.63). In rain shelter, the number of primary rhizome ranged from 4.00 (Aswathy) to 5.68 (SE 8681) followed by SE 8640 and SEHP 9 with a value of 4.45. Number of secondary rhizomes under open field condition ranged from 8.38 (Aswathy) to 13.38 (SE 8681), whereas in rain shelter secondary rhizome number ranged from 9.83 to 10.88 with the highest in the somaclone SE 8640 (10.88) and was on par with SE 8681 (10.45). Tertiary rhizome number under open field condition ranged from 11.88 (SE 86131) to 19.50 (SE 8681), whereas in rain shelter the value ranged from 9.33 (Aswathy) to 13.86 (SE 8681). Number of quaternary rhizomes of the genotypes under open field condition ranged from 2.08 to 4.85. The somaclone SE 8681 was significantly superior to others with a value of 4.85 for number of quaternary rhizomes and the lowest number was recorded in SE 86131 (2.08). In rain shelter the values for this character ranged from 2.33 to 6.00. The highest value was for the somaclone SEHP 9 (6.00) and was on par with SE 8681 (5.65). The lowest number of quaternary rhizomes was observed in SE 86131 (2.33).

Weight of mother, primary and secondary rhizomes of ginger genotypes cultivated under different growing conditions (open field and rain shelter) are depicted in the Table 21b. There was significant variation among the somaclones for the weight of mother rhizome recorded at harvest. Under open field condition, weight of mother rhizome was the highest for the somaclone SEHP 9 (12.00 g)

Table 21b. Number of rhizome of ginger genotypes under different growing conditions

Genotypes	Number of fingers							
	Primary (1^0)		Secondary (2^0)		Tertiary (3^0)		Quaternary (4^0)	
	Open field	Rain shelter	Open field	Rain shelter	Open field	Rain shelter	Open field	Rain shelter
SE 8681	5.13	5.68	13.38	10.45	13.83	13.86	4.85	5.65
SE 8640	4.25	4.75	11.18	10.88	12.13	13.68	3.50	3.38
SE 86131	4.23	4.63	10.25	9.83	11.88	12.00	2.08	2.33
SEHP 9	5.48	4.75	13.30	11.25	15.75	16.88	3.68	6.00
ASWATHY	3.63	4.00	8.38	9.83	19.50	9.33	3.00	4.18
CD (0.05)	**0.71**	**0.66**	**1.69**	**1.53**	**1.21**	**1.56**	**0.72**	**0.59**

Table 21c. Weight of finger rhizome of ginger genotypes under different growing conditions

Genotypes	Weight of mother rhizome (g)		Weight of primary rhizome (g)		Weight of secondary rhizome (g)	
	Open field	Rain shelter	Open field	Rain shelter	Open field	Rain shelter
SE 8681	10.25	9.25	17.60	16.10	15.07	14.45
SE 8640	10.25	9.50	16.10	17.65	15.08	14.06
SE 86131	9.50	9.50	15.68	15.68	14.37	12.54
SEHP 9	12.00	9.25	17.65	17.60	15.09	14.88
ASWATHY	6.50	9.00	13.90	13.90	6.33	6.00
CD (0.05)	**2.36**	**NS**	**1.59**	**1.50**	**1.68**	**1.51**

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which was on par with SE 8681 and SE 8640 (10.25 g), whereas under rain shelter condition there was no significant difference among the somaclones for this character. Weight of primary rhizome varied from 13.90 to 17.60 g. Weight of primary rhizome of the somaclone SE 8681 was significantly higher than other somaclones with a value of 17.60 g under open field condition. The check variety Aswathy registered the lowest number of quaternary rhizomes (13.90 g). In rain shelter, SE 8640 registered the highest number of quaternary rhizomes (17.65 g) which was on par with SEHP 9 (17.60 g) and the lowest was for the check variety Aswathy (13.90 g). Weight of secondary rhizomes varied among somaclones under different growing conditions. The somaclone SEHP 9 recorded the highest value (15.09 g) for this character under open field condition and it was on par with SE 8640 (15.08 g), SE 8681 (15.07 g) and SE 86131 (14.37 g). In rain shelter condition, SEHP 9 recorded the highest value (14.88 g) and the lowest was for the check variety Aswathy (6.00 g).

4.2.2 Yield

a. Fresh Yield

Significant difference was observed among the somaclones in fresh yield recorded at harvest (Table 21a.). The per plant yield of somaclones under open field condition ranged from 183.44g (SE 86131) to 253.75g (SEHP 9). Three somaclones namely SEHP 9, SE 8681 and SE 8640 yielded more than 200 g of per plant yield (253.75 g, 223.13 g and 213.13 g respectively) under open field condition. In rain shelter condition, per plant yield of somaclones ranged from 154.38 g (SE 86131) to 197.19 g (SE 8640). SE 8640 recorded significantly higher yield than other somaclones and check variety. The highest fresh rhizome yield per plot ranged from 5.87 to 8.12 kg under open field condition (Table 21). The highest value of 8.12 kg was recorded by SEHP 9 and it was on par with SE 8681 (7.14 kg) and SE 8640 (6.82 kg) and the lowest value was for the check variety Aswathy (5.93 kg) and SE 86131 (5.87 kg). In rain shelter, the yield per plot ranged from 4.94 to 6.31 kg. Among all the genotypes, SE 8640 was found superior in yield under rain shelter with 6.31 kg from 2 x 1 m^2 plot and the lowest

Table 22a. Effect of growing conditions on driage and dry yield of ginger genotypes

Genotypes	Driage (%)		Dry yield /plot (kg)		Dry yield / ha (t)	
	Open field	Rain shelter	Open field	Rain shelter	Open field	Rain shelter
SE 8681	21.23	20.22	1.52	1.04	6.06	4.14
SE 8640	18.13	17.24	1.24	1.09	4.95	4.35
SE 86131	18.80	18.02	1.10	0.89	4.41	3.56
SEHP 9	22.30	21.02	1.81	1.06	7.24	4.25
Aswathy	17.00	17.23	1.01	0.86	4.03	3.43
CD (0.05)	**3.38**	**2.97**	**0.26**	**0.20**	**0.27**	**0.73**

Table 22b. Effect of growing conditions on yield of ginger somaclone

Genotypes	Fresh yield /plot (kg)		Mean	Driage (%)		Mean
	Open field	Rain shelter		Open field	Rain shelter	
SE 8681	7.14	6.28	6.71	21.23	20.22	20.73
SE 8640	6.82	6.15	6.48	18.13	17.24	17.69
SE 86131	5.87	5.22	5.54	18.80	18.02	18.42
SEHP 9	8.12	7.15	7.63	22.30	21.02	21.66
Aswathy	5.93	4.97	5.45	17.00	17.23	17.12
CD (0.05)	**1.566**	**1.258**		**3.38**	**2.97**	
Mean	6.77	5.96		19.5	18.75	
CD (A)	0.57			NS		
CD (B)	0.91			2.06		
CD (A x B)	NS			NS		

was for SE 86131 (4.94 kg) and Aswathy (4.97 kg). Yield per hectare was worked out and presented in Table 21. SEHP 9 recorded the highest yield (32.48 t per hectare) followed by SE 8681 (28.56 t) and SE 8640 (27.28 t) and the lowest was for SE 86131(23.48 t) and Aswathy (23.72 t). The per hectare yield among somaclones ranged from 19.74 to 25.24 t under rain shelter condition. The somaclone SE 8640 registered the highest value of 25. 24 t and the lowest was for SE 86131 and Aswathy with an yield of 19 t per hectare.

b. Driage and dry yield

Driage of ginger somaclones under open field condition ranged from 17.00 22.30 % (Table 22). The highest value was registered in the somaclone SEHP 9 (22.30 %) under open field which was on par with SE 8681 (21.23 %). In the rain shelter, the driage recorded by somaclones ranged from17.23 to 21.02 %. The highest was recorded by SEHP 9 with a value of 21.02 % which was on par with SE 8681 (20.22%). The lowest value for driage was for Aswathy under both growing conditions.

Per plot dry yield of somaclones under open field condition ranged from 1.01 to 1.81 kg. The highest was for SEHP 9 (1.81 kg) followed by SE 8681 (1.52 kg) and the lowest was for Aswathy (1.01 kg). In rain shelter, the dry yield per plot ranged from 0.86 to 1.09 kg. The somaclone SE 8640 registered the highest value of 1.09 kg and was on par with SEHP 9, SE 8681 and SE 86131 with values of 1.06 kg, 1.04 kg and 0.89 kg respectively. The lowest was registered in Aswathy (0.86 kg). Computed values of dry yield per hectare of somaclones under open field condition ranged from 4.03 tonnes (Aswathy) to 7.24 t (SEHP 9) followed by SE 8681 (6.06 t) in open field. The dry yield per hectare ranged from 3.43 t (Aswathy) to 4.35 t (SE 8640) under rain shelter cultivation.

4.2.3 Physiological characters

a. Chlorophyll Index

The chlorophyll index recorded at 2 MAP ranged from 40.90 (Aswathy) to 48.47 (SEHP 9) under open field condition. The chlorophyll index was higher in

Table 23. Effect of growing conditions on chlorophyll index at different growth stages

Genotypes	Chlorophyll Index					
	2 MAP		4 MAP		6 MAP	
	Open field	Rain shelter	Open field	Rain shelter	Open field	Rain shelter
SE 8681	47.18	46.68	49.85	50.70	40.78	43.78
SE 8640	47.07	48.26	50.10	52.00	40.16	39.87
SE 86131	46.77	41.90	49.25	44.93	39.84	39.11
SEHP 9	48.47	49.42	50.78	50.63	42.17	42.92
ASWATHY	40.90	39.08	42.29	43.80	33.99	36.87
CD (0.05)	**2.76**	**5.49**	**1.23**	**1.38**	**1.86**	**2.56**

Table 24. Effect of growing conditions on photosynthetic rate ($\mu mol\ m^{-2} sec^{-1}$)

Genotypes	Photosynthetic rate 2 MAP		Photosynthetic rate 4 MAP		Mean	Photosynthetic rate 6 MAP		Mean
	Open field	Rain shelter	Open field	Rain shelter		Open field	Rain shelter	
SE 8681	13.21	14.77	24.30	18.97	21.64	15.31	12.30	13.81
SE 8640	16.58	17.06	25.97	21.98	23.97	16.42	14.43	15.43
SE 86131	10.21	14.25	21.23	16.75	18.99	14.30	11.07	12.68
SEHP 9	15.07	18.20	27.18	20.47	23.82	18.21	14.32	16.26
ASWATHY	10.61	12.60	20.92	15.83	18.37	12.23	9.02	10.62
CD (0.05)	**0.67**	**0.89**	**1.67**	**1.35**		**1.44**	**1.55**	
Mean			23.92	18.80		15.29	12.23	
CD (A)			0.65			0.20		
CD (B)			1.03			0.32		
CB (A x B)			NS			0.45		

somaclones SEHP 9, SE 8681 and SE 8640 at all growth stages where as SE 86131 and Aswathy recorded lower values for this character at all growth stages. SEHP 9 recorded highest value of 48.47 at 2 month stage followed by SE 8681 (47.18), SE 8640 (47.07) and SE 86131 (46.77) (Table 23 and Plate 9). In rain shelter, SEHP 9 registered the highest value of 49.42 and was on par with SE 8640 (48.26) followed by SE 8681 (46.68) and SE 86131 (41.90). The lowest was for the check variety Aswathy (39.08). The chlorophyll index was maximum at 4 MAP under both growing conditions and later it decreased. The somaclone SEHP 9 recorded the maximum value of 50.78 at 4 month stage under open field and was on par with SE 8640 (50.00) and SE 8681 (49.85) followed by SE 86131 (49.25). The lowest was for the check variety Aswathy (42.29) under open field condition. In rain shelter, highest value was recorded by the somaclone SE 8640 (52.00), SE 8681 (50.70) and SEHP 9 (50.63) followed by SE 86131 with a value of 44.93 and the lowest value was for the check variety Aswathy (43.80). During 6 MAP, the somaclone SEHP 9 registered the highest value of 42.17 and was on par with SE 8681(40.78) followed by SE 8640 (40.16) and SE 86131 (39.84). The lowest value was for Aswathy (33.99). In rain shelter, highest value for chlorophyll index was recorded by SE 8681 (43.87) and SEHP 9 (42.92) followed by SE 8640 (39.87) and SE 86131 (39.11). The lowest value (36.87) was registered in Aswathy.

b. Photosynthetic Rate

The photosynthetic rate measured during 2 MAP, 4 MAP and 6 MAP for the somaclones are given in Table 24. At 2 MAP, photosynthetic rate among ginger somaclones ranged from 10.21 to 16.58 µmol $m^{-2}sec^{-1}$ under open field condition. The somaclone SE 8640 registered the highest value of 16.58 µmol $m^{-2}sec^{-1}$ followed by SEHP 9 (15.07 µmol $m^{-2}sec^{-1}$) and the lowest value was for SE 86131 (10.61 µmol $m^{-2}sec^{-1}$) and Aswathy (10.61 µmol $m^{-2}sec^{-1}$). In rain shelter, the somaclone SEHP 9 (18.20 µmol $m^{-2}sec^{-1}$) recorded maximum value followed by SE 8640 (17.06 µmol $m^{-2}sec^{-1}$). The check variety Aswathy registered the lowest value (12.60 µmol $m^{-2}sec^{-1}$). During 4 MAP, the somaclone SEHP 9 recorded highest value (27.18 μmol $m^{-2}sec^{-1}$) which was on par with SE 86 40 (25.97 μmol $m^{-2}sec^{-1}$) and the lowest value (20.93 μmol $m^{-2}sec^{-1}$) was for the check variety Aswathy under open field condition. In rain shelter, SE8640 recorded the highest value of 21.98 μmol $m^{-2}sec^{-1}$ followed by SEHP 9 (20.47 μmol $m^{-2}sec^{-1}$) and the lowest was for Aswathy (15.83 μmol $m^{-2}sec^{-1}$) and SE 86131(16.75 μmol $m^{-2}sec^{-1}$). At 6 MAP, SEHP 9 recorded the highest value of 18.21 μmol $m^{-2}sec^{-1}$ followed by SE 8640 (16.42 μmol $m^{-2}sec^{-1}$) and SE 8681 (15.31 μmol $m^{-2}sec^{-1}$) under open field. The lowest rate was for Aswathy (12.23 μmol $m^{-2}sec^{-1}$) under this condition. In rain shelter, SE 8640 registered the highest value of (14.43 μmol $m^{-2}sec^{-1}$) which was on par with SEHP 9 (14.32 μmol $m^{-2}sec^{-1}$) and the lowest value was for Aswathy (9.02 μmol $m^{-2}sec^{-1}$).

Mean values for photosynthetic rate was significantly higher under open field condition (23.93 μmol $m^{-2}sec^{-1}$) than in rain shelter (18.80μmol $m^{-2}sec^{-1}$) at 4 month stage. Among the somaclones, SE 8640 recorded the highest value 0f 23.97 μmol $m^{-2}sec^{-1}$ followed by SEHP 9 (23.82 μmol $m^{-2}sec^{-1}$) irrespective of the growing conditions at 4 MAP.

c. Transpiration Rate

The transpiration rate was recorded highest for the somaclone SE 8681 with a value of 5.51 μmol $m^{-2}sec^{-1}$ followed by SEHP 9 (4.90 μmol $m^{-2}sec^{-1}$), SE 8640 (4.87 μmol $m^{-2}sec^{-1}$) and SE 86131(4.74 μmol $m^{-2}sec^{-1}$) under open field condition during 2 MAP (Table 25). The lowest was for Aswathy (4.62 μmol $m^{-2}sec^{-1}$). In rain shelter, SE 8640 (4.51 μmol $m^{-2}sec^{-1}$) and SE 8681(4.40 μmol $m^{-2}sec^{-1}$) recorded the highest value and followed by SEHP 9 and SE 86131(3.53 μmol $m^{-2}sec^{-1}$ and 3.50 μmol $m^{-2}sec^{-1}$ respectively). At 4 MAP, SE 8681 registered highest value (4.99 μmol $m^{-2}sec^{-1}$) for transpiration rate and was on par with SEHP 9 (4.65 μmol $m^{-2}sec^{-1}$) followed by SE 8640 (4.36 μmol $m^{-2}sec^{-1}$) under open field condition. The lowest value was for Aswathy (3.98 μmol $m^{-2}sec^{-1}$). In rain shelter, SE 8640 recorded highest transpiration rate with a value of 3.64 μmol $m^{-2}sec^{-1}$ and on par with SE 8681 (3.18 μmol $m^{-2}sec^{-1}$) and SEHP 9 (3.01

IRGA

(Photosynthetic rate, Transpiration rate & Stomatal conductance)

SPAD meter (Chlorophyll Index)

Plate 9. Taking observations on physiological parameters

Table 25. Effect of growing conditions on transpiration rate (μmol $m^{-2}sec^{-1}$)

Genotypes	Transpiration rate 2MAP		Transpiration rate 4 MAP		Mean	Transpiration rate 6 MAP		Mean
	Open field	Rain shelter	Open field	Rain shelter		Open field	Rain shelter	
SE 8681	5.51	4.40	4.99	3.18	4.08	3.62	1.12	0.07
SE 8640	4.87	4.51	4.36	3.64	3.99	1.09	1.07	0.03
SE 86131	4.74	3.50	4.09	2.92	3.50	1.11	0.94	0.02
SEHP 9	4.90	3.53	4.65	3.01	3.83	2.05	1.09	0.03
ASWATHY	4.62	2.34	3.98	2.45	3.22	0.82	0.76	0.02
CD (0.05)	**0.25**	**0.39**	**0.59**	**0.69**		**0.66**	**1.99**	
Mean			4.41	3.05		1.74	0.99	
CD (A)			0.05			0.01		
CD (B)			0.07			0.02		
CB (A x B)			NS			NS		

Table 26. Effect of growing conditions on stomatal conductance (m μmol $m^{-2}sec^{-1}$)

Genotypes	Stomatal conductance 2 MAP		Stomatal conductance 4 MAP		Mean	Stomatal conductance 6 MAP		Mean
	Open field	Rain shelter	Open field	Rain shelter		Open field	Rain shelter	
SE 8681	0.07	0.05	0.11	0.08	0.09	0.08	0.05	0.07
SE 8640	0.09	0.08	0.11	0.10	0.11	0.03	0.02	0.03
SE 86131	0.07	0.05	0.09	0.07	0.08	0.03	0.01	0.02
SEHP 9	0.09	0.06	0.27	0.09	0.18	0.04	0.02	0.03
ASWATHY	0.07	0.05	0.08	0.06	0.07	0.02	0.01	0.02
CD (0.05)	**0.01**	**0.01**	**0.11**	**NS**		**0.04**	**0.02**	
Mean			0.13	0.08		0.04	0.02	
CD (A)			0.05			0.01		
CD (B)			0.07			0.02		
CB (A x B)			NS			NS		

μmol $m^{-2}sec^{-1}$). The lowest was for Aswathy with a value of 2.45 μmol $m^{-2}sec^{-1}$. During 6 MAP, the highest transpiration rate of 3.62 μmol $m^{-2}sec^{-1}$ was recorded in the somaclone SE 8681 followed by SEHP 9 (2.05 μmol $m^{-2}sec^{-1}$) under open field condition and the lowest was for Aswathy (0.82 μmol $m^{-2}sec^{-1}$). Under rain shelter, the transpiration rate ranged from 0.76 to 1.12 μmol $m^{-2}sec^{-1}$ with highest value in SE 8681and on par with SEHP 9 (1.09 μmol $m^{-2}sec^{-1}$) and SE 8640 (1.07 μmol $m^{-2}sec^{-1}$) and the lowest in Aswathy with a value of 0.76 μmol $m^{-2}sec^{-1}$.

Mean transpiration rate recorded at 4 month growth stage was significantly higher under open field condition (4.41 μmol $m^{-2}sec^{-1}$) compared to rain shelter (3.04 μmol $m^{-2}sec^{-1}$) and at 6 month stage also values were higher under open field. The somaclone SE 8681 recorded the highest mean value (4.08 μmol $m^{-2}sec^{-1}$) followed by SE 8640 (3.99 μmol $m^{-2}sec^{-1}$) regardless of the growing conditions at 4 month stage.

d. Stomatal Conductance

The stomatal conductance was recorded maximum (0.09 m μmol $m^{-2}sec^{-1}$) for the somaclone SE 8640 and SEHP 9 (0.06 m μmol $m^{-2}sec^{-1}$) followed by SE 8681, SE 86131 and Aswathy recording a value of 0.07 m μmol $m^{-2}sec^{-1}$under open field condition at 2 MAP (Table 26). In rain shelter, the somaclone SE 8640 registered the highest value of 0.08 m μmol $m^{-2}sec^{-1}$ which was on par with SEHP 9 (0.06 m μmol $m^{-2}sec^{-1}$) followed by SE 8681, SE 86131 and Aswathy with a value of 0.05 m μmol $m^{-2}sec^{-1}$. During 4 MAP, the highest value was registered for SEHP 9 (0.27 m μmol $m^{-2}sec^{-1}$) and the lowest was for Aswathy (0.08 m μmol $m^{-2}sec^{-1}$). There was no significant difference among the somaclones on stomatal conductance under rain shelter condition. The values ranged from 0.06 to 1.10 m μmol $m^{-2}sec^{-1}$). During 6 MAP, stomatal conductance under open field condition ranged from 0.01 (Aswathy) to 0.05 (SE 8681). Under rain shelter, SE 8681 recorded the highest stomatal conductance with a value of 0.08 m μmol $m^{-2}sec^{-1}$ on par with SEHP 9 (0.04 m μmol $m^{-2}sec^{-1}$) and the lowest value for stomatal conductance was registered in Aswathy (0.08 m μmol $m^{-2}sec^{-}1$).

Stomatal conductance (mean values) was also significantly higher under open field condition (0.132 m μmol $m^{-2}sec^{-1}$) compared to rain shelter (0.08 m μmol $m^{-2}sec^{-1}$). Regardless of the growing conditions, the somaclone SEHP 9 (0.18 m μmol $m^{-2}sec^{-1}$) registered the highest stomatal conductance followed by SE 8640 (0.11 m μmol $m^{-2}sec^{-1}$) at 4 month stage.

4.2.4 Pest and disease incidence

Incidence of shoot borer attack and rhizome rot in genotypes under different growing conditions was observed at 6 month stage (Table 21d and Plate 10). Shoot borer incidence under open field condition varied from 5.21 % (SEHP 9) to 8.33 % (SE 86131), whereas in rain shelter, the incidence ranged from 3.13 % (SE 8681) to 5.21 % (SE 8640)

Rhizome rot incidence was also recorded at 6 MAP and under open feld condition incidence was more and varied from 4.7 % (SEHP 9) to 9.87 % (Aswathy). Inside rain shelter rhizome rot incidence ranged from 4.17 % (SEHP 9) to 7.21 % (Aswathy). Results revealed lesser incidences of pest and disease under rain shelter condition compared to open field. Among the somaclones, SEHP 9 showed minor attack of stem borer and rhizome rot under both the growing conditions.

Table 21 d. Shoot borer and rhizome rot incidence at 6 months stage

Genotypes	Shoot borer (%)		Rhizome rot (%)	
	Open field	Rain shelter	Open field	Rain shelter
SE 8681	6.25	3.13	9.37	5.21
SE 8640	7.29	5.21	7.29	6.25
SE 86131	8.33	4.79	8.33	6.25
SEHP 9	5.21	4.17	4.71	4.17
ASWATHY	8.33	7.29	9.87	7.21
CD (0.05)	1.01	1.21	1.85	1.02

Stem borer

Rhizome rot

Plate 10. Pest and diseases incidence in ginger

4.3 QUALITY PROFILING OF GINGER GENOTYPES UNDER DIFFERERNT GROWING CONDITIONS AND DIFFERERNT MATURITY STAGES.

Rhizomes of four somaclones (SE 8681, SE 8640, SE 86131, SEHP 9) and KAU released variety Aswathy grown under different conditions were harvested at vegetable maturity (5 MAP) and full maturity (7 MAP) stage for analyzing quality parameters.

4.3.1. Volatile oil

Volatile oil content of somaclones at 5 and 7 MAP under different growing conditions are given in Table 27. Volatile oil percentage ranged from 2.26 to 4.45 among the somaclones at 5 MAP under open field condition. The highest value for volatile oil was recorded in SE 8640 under both growing conditions *viz.,* open field (4.45 %) and rain shelter (4.67 %) which was on par with the check Aswathy under both the growing conditions (3.50 % and 3.63 % respectively). Similarly at 7 MAP, the highest value for volatile oil was recorded in SE 8640 under both growing conditions *viz.,* open field (3.30 %) and rain shelter (3.61 %) which was on par with the check Aswathy under both the growing conditions (2.37 % and 2.63 %).

4.3.2 Oleoresin

Oleoresin content obtained at 5 and 7 MAP in different somaclones grown under different growing conditions is given in Table 28. Oleoresin percentage ranged from 4.12 to 6.01 among the somaclones at 5 MAP under open field condition. The highest value (6.01 %) was recorded by SEHP 9 which was on par with SE 86131 (5.71 %) and Aswathy (5.63 %) and was lowest was for SE 8640 (4.12 %). Under rain shelter, SEHP 9 recorded the highest value of 6.72 % which was on par with SE 86131 (6.42 %), Aswathy (6.23 %) and SE 8681 (6.12 %). At 7 MAP, the oleoresin percentage under open field condition ranged from 3.80 to 4.58 among the somaclones. The highest was for Aswathy with 4.58 % of

Table 27. Volatile oil content at different growing conditions and at different growth stages

Genotypes	Volatile oil (%) 5 MAP		Mean	Volatile oil (%) 7 MAP		Mean
	Open field	Rain shelter		Open field	Rain shelter	
SE 8681	2.26	2.30	2.63	1.96	2.24	2.12
SE 8640	4.45	4.67	4.56	3.30	3.61	3.45
SE 86131	2.42	2.80	2.61	1.75	2.11	1.93
SEHP 9	2.40	2.89	2.64	2.29	2.55	2.45
ASWATHY	3.50	3.63	3.56	2.37	2.63	3.00
CD (0.05)	**1.88**	**0.93**		**0.75**	**1.35**	
Mean	3.01	3.27		2.38	2.78	
CD (A)	NS			NS		
CD (B)	0.74			0.57		
CB (A x B)	NS			NS		

Table 28. Oleoresin content at different growing conditions and at different maturity stages

Genotypes	Oleoresin (%) 5 MAP		Mean	Oleoresin (%) 7 MAP		Mean
	Open field	Rain shelter		Open field	Rain shelter	
SE 8681	5.05	6.12	5.56	4.51	5.42	4.97
SE 8640	4.12	5.21	4.67	4.05	4.76	4.41
SE 86131	5.71	6.42	6.07	3.80	4.42	4.36
SEHP 9	6.01	6.72	6.36	3.81	4.70	4.11
ASWATHY	5.63	6.23	5.93	4.58	5.49	4.26
CD (0.05)	**0.38**	**0.96**		**0.68**	**0.52**	5.04
Mean	5.30	6.14		4.15	4.96	
CD (A)	NS			NS		
CD (B)	0.67			0.56		
CB (A x B)	NS			NS		

oleoresin and the lowest was for SE 86131 (3.80 %). In rain shelter, Aswathy registered the highest value of 5.49 % which was on par with SE 8681 (5.42 %) and the lowest was for SE 86131 (4.42 %).

4.3.3 Crude fibre

Crude fibre content varied from 1.70 to 1.98 % among the somaclones at five month maturity under open field condition (Table 29). The lowest crude fibre content (1.70 %) was registered by SE 86131 and the highest in the somaclones SEHP 9 and Aswathy with a value of 1.98 %. In rain shelter, SE 8681 registered the lowest value (1.46 %) and the highest crude fibre content (1.87 %) was registered in Aswathy. At seven month maturity, SE 8640 recorded the lowest crude fiber content (2.45 %) under open field condition and the highest was registered in SEHP 9 (3.43 %). In rain shelter, SE 8640 recorded the lowest value of 2.26 % and the highest was for SEHP 9 (3.12 %).

4.3.4 Starch

Starch content showed significant variation among the somaclones (Table 11). The highest starch content was observed in the check variety Aswathy with 45.30 % and the lowest was for the somaclone C 78284 at seven month maturity. The somaclones SE 8626 and CHP 99 recorded starch content more than 40 % at this growth stage compared to others.

4.3.5 Gingerol and shogaol content

Pungent principles of ginger such as gingerols and shogaol varied in their presence among the somaclones grown under different growing conditions (Table 21c.). Under open field condition, the percentage of (6)- Gingerol was found to be highest in the somaclones SE 8681 and SE 8640 with value of 0.63 %, whereas under rain shelter condition, Aswathy recorded the highest value (0.73 %). (8)-Gingerol percentage under open field condition varied from 0.08 % (SE 86131) to 0.12 % (Aswathy). In rain shelter, Aswathy and SEHP 9 registered the highest value (0.09 %) for (8) –Gingerol content. (10)-Gingerol content under open field

Table 29a. Crude fibre content at different growing conditions and at different maturity stages

Genotypes	Crude fibre (%) 5 MAP		Mean	Crude fibre (%) 7 MAP		Mean
	Open field	Rain shelter		Open field	Rain shelter	
SE 8681	1.82	1.46	1.64	3.01	2.98	2.99
SE 8640	1.86	1.76	1.81	2.45	2.26	2.36
SE 86131	1.70	1.53	1.62	2.77	2.47	2.62
SEHP 9	1.98	1.83	1.91	3.43	3.12	3.28
ASWATHY	1.98	1.87	1.93	3.10	3.02	3.06
CD (0.05)	**0.17**	**0.29**		**0.71**	**0.48**	
Mean	1.87	1.69		2.95	2.77	
CD (A)	0.08			NS		
CD (B)	0.12			0.39		
CB (A x B)	NS			NS		

Table 29 b. Gingerol and shogaol content under different growing conditions

Genotypes	(6) -gingerol		(8)- gingerol		(10)- gingerol	
	Open field	Rain shelter	Open field	Rain shelter	Open field	Rain shelter
SE 8681	0.63	0.58	0.10	0.08	0.10	0.10
SE 8640	0.63	0.55	0.10	008	0.10	0.09
SE 86131	0.55	0.45	0.08	0.05	0.09	0.06
SEHP 9	0.08	0.69	0.10	0.09	0.01	0.10
ASWATHY	0.10	0.73	0.12	0.09	0.15	0.10
CD (0.05)	**0.04**	**0.02**	**0.03**	**0.01**	**0.03**	**0.02**

Table 29 c. Total gingerol and shogaol content under different growing conditions

Genotypes	Total gingerol (%)		Total shogaol (%)		Total gingerol + shogaol (%)	
	Open field	Rain shelter	Open field	Rain shelter	Open field	Rain shelter
SE 8681	0.83	0.76	0.14	0.07	0.97	0.83
SE 8640	0.83	0.72	0.13	0.05	0.96	0.77
SE 86131	0.72	0.56	0.08	0.05	0.80	0.61
SEHP 9	0.19	0.88	0.01	0.05	0.20	0.93
ASWATHY	1.37	0.92	0.09	0.10	1.46	1.02
CD (0.05)	**0.04**	**0.03**	**0.02**	**0.03**	**0.04**	**0.03**

condition ranged from 0.01 % (SEHP 9) to 0.15 % (Aswathy) under open field condition, whereas in rain shelter SE 8681, SEHP 9 and Aswathy registered the highest value of 0.10 % followed by SE 8640 (0.09 %). The lowest value for (10)-Gingerol was for the somaclone SE 86131 (0.06 %). Total content of gingerol was the highet in Aswathy (1.37 %) under open field condition and the lowest was for SEHP P (0.19 %). Aswathy recorded the highest total gingerol content (0.92 %) in rain shelter condition also and the lowest was for SE 86131 (0.56 %). The check variety Aswathy registered the highest value for total gingerol and shogaol content under both the growing conditions (open field -1.46 % and 1.02 % rain shelter) compared to the somaclones.

4.4 SCREENING GINGER GENOTYPES FOR PRODUCT DEVELOPMENT

Ten ginger somaclones and Aswathy were utilized for product development.

4.4.1. Easiness in peeling

Easiness in peeling was assessed for ten somaclones and the check variety Aswathy, based on time required for hand peeling at five and seven month maturity stages (Table 30). Somaclones at five months maturity differed in the character for easiness in peeling. It was observed that four somaclones SE 86 26, SE 86 83, SE 86 102 and CHP 282 were very easy to peel (<4 minutes) compared to other somaclones and variety Aswathy, which took less than four minutes to peel 100 grams of samples. Other six somaclones namely C 86 26, CHP 118, C 78 284, SE 86 42, C 86 32 and CHP 99 were moderately easy to peel (4 – 6 minutes) and the check Aswathy was difficult to peel compared to other somaclones.

At seven months maturity, SE 8683 was found to be much easy to peel (<4 minutes) compared to other somaclones and Aswathy. Majority of the somaclones at this age were categorized under moderately easy to peel, they are, SE 8626, SE 86102, C 8626, CHP 118, C 78284, SE 8642 and C 8632. The somaclones CHP 99, CHP 282 and the check variety Aswathy were found to be difficult types to peel at seven month stage.

Table 30. Easiness in peeling of ginger somaclones

Easiness in peeling	Time taken (minutes)	Somaclones	
		5 month stage	7 month stage
Easy	<4	SE 86 26, SE 86 83, SE 86 102, CHP 282	SE 86 83
Moderate	4-6	C 86 26, CHP 118, C 78 284, SE 86 42, C 86 32, CHP 99	SE 86 26, SE 86 102, C 86 26, CHP 118, C 78 284, SE 86 42, C 86 32
Difficult	>6	Aswathy	Aswathy, CHP 99, CHP 282

Three products were prepared and the products are:

a) Candy
b) Flakes
c) Powder

The prepared products were packed in HDPE cover and stored for six months under room temperature. Sensory evaluation for colour, flavour, texture and overall acceptability of these products was done by a panel of 15 semi trained judges on a nine point hedonic scale after preparation of products and also during storage (Plates 4, 5 and 6).

4.4.2. Recovery of ginger products

a. Candy

The recovery of ginger candy of ten somaclones ranged from 53.41 % to 78.41 % (Table 31). The somaclones SE 8683, SE 86102, CHP 118, CHP 282 and Aswathy recorded recovery more than 70 percentage among the somaclones. The somaclone SE 8642 recorded the highest recovery percentage of 78.41, followed by C 8626 (78.24 %). Somaclone SE 8626 registered lowest recovery (53.41 %).

b. Flakes

The recovery of ginger flakes ranged from 6.40 % to 18.21 % (Table 31). Four somaclone such as SE 8626, C 8626, CHP 118 and SE 8642 showed more than 10 percentage recovery. The somaclone SE 8626 recorded significantly

Table 31. Product recovery from ginger genotypes

Genotypes	Recovery (%)		
	Candy	Flakes	Powder
SE 8626	72.97	18.21	15.55
SE 8683	28.40	8.41	17.21
C 8626	53.41	16.80	15.40
CHP 118	73.40	16.60	18.40
C 78284	76.01	8.40	15.20
SE 86102	74.01	6.40	22.41
SE 8642	78.41	7.41	28.80
C 8632	77.41	16.00	17.80
CHP 99	67.20	7.61	19.05
CHP 282	78.24	7.41	20.41
Aswathy	71.40	10.00	21.80
CD (0.05)	0.01	0.02	0.06

Table 32. Effect of storage on moisture content (%) of ginger candy

Genotypes	Moisture content (%)			
	Initial	2 MAS	4 MAS	6 MAS
SE 8626	6.00	6.14	11.31	11.14
SE 8683	7.41	7.49	11.12	11.12
C 8626	6.00	6.94	10.83	10.83
CHP 118	6.12	6.84	10.02	10.01
C 78284	3.90	4.67	9.11	9.11
SE 86102	5.80	6.28	9.52	9.52
SE 8642	6.40	6.88	8.42	8.42
C 8632	5.81	6.12	8.64	8.64
CHP 99	4.06	4.53	8.67	8.67
CHP 282	4.27	4.78	8.22	8.22
Aswathy	5.54	7.24	10.12	10.12
CD (0.05)	0.93	0.27	1.08	1.07

highest value of recovery (18.21 %) followed by C 8626 (16.80 %). The lowest recovery was registered in SE 86102 (6.40 %).

c. Powder

The recovery of ginger powder ranged from 15.20 % to 28.80 % (Table 31). Somaclones SE 86102, CHP 282 and check variety Aswathy showed recovery more than 20 percentage. The somaclone SE 8642 recorded significantly highest value of recovery (18.21 %) to other somaclones and check variety followed by SE 86102 (22.41 %). The lowest recovery was registered in C 78284 (15.20 %).

4.4.3. STABILITY OF QUALITY PARAMETERS OF GINGER CANDY DURING STORAGE

4.4.3.1 Physical characteristics

4.4.3.1.1 Moisture content

Initial moisture content of ginger candy from the somaclones and check variety ranged from 3.90 to 7.41 %. Minimum moisture content was observed in somaclones C 78284 (3.90 %), CHP 99 (4.06 %) and CHP 282 (4.27 %). The highest was in SE 8683 (7.41 %).

During 2 MAS, the moisture content of samples ranged from 4.53 to 7.49 %. Minimum moisture content was observed in CHP 99 (4.5 %) and CHP 282 (4.78 %) and highest in check Aswathy (7.24 %).

There was not much change in moisture content of ginger candy from all somaclones and Aswathy during three months after storage (MAS) compared to initial stage. Moisture content ranged from 8.22 to 11.31 % at 2 MAS. The somaclone SE 8642 recorded highest value (11.14 %) followed by SE 8683 (11.12 %) and C 8626 (10.83 %). Somaclones C 78284, SE 8642, C 8632, CHP 99 and CHP 282 recorded moisture content below seven percentage. Minimum moisture content (8.22 %) was observed in CHP 282

At 6 MAS, moisture content of ginger candy ranged from 8.22 to 11.14 %, with somaclone SE 8626 recording highest value (11.14 %) which was on par with SE 8683 (11.12 %) and C 8626 (10.83 %) (Table 32). Somaclones C 78284, SE 8642, C 8632, CHP 99 and CHP 282 recorded moisture content above seven percentage. Minimum moisture content (8.22 %) was observed in CHP 282.

4.4.3.1.2 Colour

Colour of ginger candy was assessed by using Royal Horticulture Society Colour Chart (Edition V) (Table 33). Initially, SE 8626 and C 78284 exhibited Light Orangish Yellow colour (19 A), SE 8683, C 8626, CHP 118 and CHP 118 showed Light Yellow colour (18 A), SE 86102 exhibited Moderate Orangish Yellow colour (164 B), CHP 282 exhibited Moderate Yellow colour (162 A) and SE 8642, C 8632 and Aswathy showed Pale Yellow colour (18 A).

There was no notable colour change in ginger candy from different somaclones during 2 MAS, whereas the variety Aswathy showed a little colour change from Pale Yellow (18 D) to Pale Yellow (20 D).

During 6 MAS, there was no notable colour change in ginger candy from somaclones, but Aswathy showed a colour change from Pale Yellow (18 D) to Pale Yellow (20 D).

4.4.3.2 Biochemical parameters

4.4.3.2.1 TSS (^{0}Brix)

The TSS content of ginger candy ranged from 66.10 to 69.50 ^{0}Brix and the highest TSS content was for SE 8626 recording highest value of 69.50 followed by CHP 282 (68.10 ^{0}Brix) (Table 34). Minimum TSS content (66.10 ^{0}Brix) was registered in CHP 99.

TSS content of ginger candy showed a decreasing trend during storage. Ginger candy from SE 8683 (68.02 ^{0}Brix) and SE 8626 (68.01 ^{0}Brix) recorded high TSS content after two months of storage followed by SE 8642 (67.90 ^{0}Brix) Aswathy (67.50 ^{0}Brix) and CHP 282 (66.50 ^{0}Brix). Minimum TSS content was observed C 8632 with a value of 64.10 ^{0}Brix.

At 4 MAS, the TSS content of ginger candy ranged from 41.00 to 55.50 ^{0}Brix and candy from SE 8642 showed the highest value (55.50 ^{0}Brix) followed

Table 33. Colour description of ginger candy in storage

Genotypes	Intial	2 MAS	4 MAS	6 MAS
SE 8626	Light Orangish Yellow (19A)	Light Orangish Yellow (19A)	Light Orangish Yellow (19A)	Light Orangish Yellow (19A)
SE 8683	Light Yellow (18A)	Light Yellow (18A)	Light Yellow (18A)	Light Yellow (18A)
C 8626	Light Yellow (18A)	Light Yellow (18A)	Light Yellow (18A)	Light Yellow (18A)
CHP 118	Light Yellow (18A)	Light Yellow (18A)	Light Yellow (18A)	Light Yellow (18A)
C 78284	Light Orangish Yellow (19A)	Light Orangish Yellow (19A)	Light Orangish Yellow(19A)	Light Orangish Yellow (19A)
SE 86102	Moderated Orangish Yellow (164B)	Moderated Orangish Yellow (164B)	Moderated Orangish Yellow (164B)	Moderated Orangish Yellow (164B)
SE 8642	Pale Yellow (18B)	Pale Yellow (18B)	Pale Yellow (18B)	Pale Yellow (18B)
C 8632	Pale Yellow (18D)	Pale Yellow (18D)	Pale Yellow (18D)	Pale Yellow (18D)
CHP 99	Light Yellow (18A)	Light Yellow (18A)	Light Yellow (18A)	Light Yellow (18A)
CHP 282	Moderate Yellow (162A)	Moderate Yellow (162A)	Moderate Yellow (162A)	Moderate Yellow (162A)
Aswathy	Pale Yellow (18D)	Pale Yellow (18D)	Pale Yellow (20D)	Pale Yellow (20D)

MAS- Months After Storage

by SE 8683 (52.50 ^{0}Brix) recorded highest TSS content and the minimum TSS content was observed C 8632 (41.00 ^{0}Brix).

At 6 MAS, the TSS content of ginger candy ranged from 31.40 to 37.50 ^{0}Brix and candy from SE 8642 showed the highest value (37.50 ^{0}Brix) followed by SE 8683 (36.20 ^{0}Brix) recorded highest TSS content and the minimum TSS content was observed SE 86102 (32.06 ^{0}Brix).

4.4.3.2.2 ***pH***

Initial pH content of ginger candy from different somaclones was observed from 3.50 to 4.10, with the maximum in somaclone CHP 282 and variety Aswathy with a value of 4.10 which was followed by other four somaclones SE 8681, SE 8683, C 8626 and SE 86102 with a pH value of 4.00. The minimum value for pH was observed in somaclone CHP 118 (Table 35).

During 2 MAS, pH content of ginger candy from different somaclones showed a decreasing trend with values ranging from 3.00 to 3.81. The maximum pH was observed in somaclone CHP 282 and variety Aswathy with a value of 4.10 and was followed by other four somaclones SE 8681, SE 8683, C 8626 and SE 86102 with a pH value of 4.00. The minimum value for pH was observed in somaclone CHP 118.

pH content of ginger candy from different somaclones at 4 MAS, showed a decreasing trend with values ranging from 2.00 to 3.63. The maximum pH was registered in somaclone SE 86102 with a value of 3.63 and was followed by other three somaclones SE 8626, SE 8683, C 8626 and CHP 282 with a pH value of 3.56. The minimum value for pH was observed in the Aswathy (2.00).

At 6 MAS, pH content of ginger candy from different somaclones ranged from 3.15 to 3.52. The maximum pH was registered in somaclone SE 86102 with a value of 3.52 and was followed by CHP 118 (3.40) ad CHP 99 (3.41). The minimum value for pH was observed in Aswathy (1.81).

Table 34. Effect of storage on TSS (^{0} Brix) of ginger candy

Genotypes	TSS (^{0} Brix)			
	Initial	2 MAS	4 MAS	6 MAS
SE 8626	69.50	68.01	51.12	36.00
SE 8683	69.20	68.02	52.50	35.00
C 8626	68.50	65.47	44.00	32.50
CHP 118	66.25	64.50	44.18	31.40
C 78284	67.16	66.36	43.94	34.10
SE 86102	67.50	64.89	45.50	32.06
SE 8642	69.31	67.90	55.50	37.50
C 8632	66.10	64.10	41.00	34.15
CHP 99	66.10	65.65	42.00	33.12
CHP 282	68.10	66.50	43.73	34.12
Aswathy	68.00	67.50	41.62	34.12
CD (0.05)	1.04	1.54	1.33	0.74

Table 35. Effect of storage on pH of ginger candy

Genotypes	pH			
	Initial	2 MAS	4 MAS	6 MAS
SE 8626	4.00	3.92	3.56	3.21
SE 8683	4.00	3.81	3.56	3.20
C 8626	4.00	3.50	3.45	3.30
CHP 118	3.50	3.50	3.45	3.40
C 78284	3.70	3.51	3.44	3.21
SE 86102	4.00	3.81	3.63	3.52
SE 8642	3.60	3.40	3.32	3.15
C 8632	3.63	3.41	3.30	3.20
CHP 99	3.56	3.40	3.41	3.41
CHP 282	4.10	3.81	3.56	3.45
Aswathy	4.10	3.00	2.00	1.81
CD (0.05)	0.03	0.03	0.05	0.05

4.4.3.2.3 ***Titratable acidity***

Titratable acidity observed initially, for ginger candy from different somaclones ranged between 0.10 to 0.19 %, with the maximum in somaclones CHP 118, SE 86102, CHP 99 and CHP 282 (0.19 %) (Table 36).The minimum value (0.10 %) for titratable acidity was observed in somaclones SE 8626, C 8626 and SE 8642.

At 2 MAS, titratable acidity of ginger candy showed an increasing trend with values ranging from 0.11 to 0.23 %. The maximum titratable acidity was observed in the variety Aswathy (0.23 %) which was on par with CHP 99 (0.22 %) followed by CHP 118 and CHP 282 with 0.21 % titratable acidity. The minimum titratable acidity was observed in somaclones SE 8626 (0.11 %) and SE 8642 (0.12 %).

Titratable acidity of ginger candy at 4 MAS ranged from 0.15 to 0.24 %. The maximum titratable acidity was registered in Aswathy with 0.24 % which was on par with C 78284, CHP 99 and CHP 282 with 0.23 % titratable acidity. The minimum value for pH was observed in SE 8642 (0.15 %).

At 6 MAS, titratable acidity ranged from 0.16 to 0.26 %. The maximum titratable acidity (0.26 %) was registered in somaclone C 78284 and CHP 99 followed by CHP 282 and Aswathy with a value of 0.24 %. The minimum value was observed in SE 8642 (0.16 %).

4.4.3.3 Enumeration of microbial flora

4.4.3.3.1 Bacterial population

In ginger candy, no bacterial growth was detected in any of the samples immediately after preparation and also at 2 and 4 MAS (Table 37 and Plate 11). However it was found in few somaclones after 6 months of storage such as CHP 118 (3.20×10^{-5}), C 78284 (3.03×10^{-5}) and CHP 282 (3.00×10^{-5}).

4.4.3.3.2 Mould population

Initially no mould growth was detected any of the samples. During second and fourth months after storage also candy was devoid of any mould growth. But

Table 36. Effect of storage on titratable acidity (%) of ginger candy

Genotypes	Titratable acidity (%)			
	Initial	2 MAS	4 MAS	6 MAS
SE 8626	0.10	0.11	0.19	0.20
SE 8683	0.13	0.13	0.20	0.20
C 8626	0.10	0.13	0.17	0.18
CHP 118	0.19	0.21	0.21	0.22
C 78284	0.16	0.17	0.23	0.26
SE 86102	0.19	0.19	0.20	0.23
SE 8642	0.10	0.12	0.15	0.16
C 8632	0.17	0.19	0.21	0.22
CHP 99	0.19	0.22	0.23	0.26
CHP 282	0.19	0.21	0.23	0.24
Aswathy	0.16	0.23	0.24	0.24
CD (0.05)	0.01	0.01	0.03	0.02

Table 38. Effect of storage on moisture content (%) of ginger flakes

Genotypes	Moisture content (%)			
	Initial	2 MAS	4 MAS	6 MAS
SE 8626	7.37	7.34	8.00	8.00
SE 8683	6.00	6.40	6.55	6.79
C 8626	6.00	6.51	7.00	7.28
CHP 118	7.10	7.15	7.79	8.00
C 78284	6.31	6.30	7.00	7.08
SE 86102	7.40	7.80	8.05	8.10
SE 8642	6.00	6.40	6.59	6.85
C 8632	7.94	8.35	8.65	9.10
CHP 99	7.00	6.70	7.01	7.84
CHP 282	7.00	6.01	6.81	7.83
Aswathy	7.05	7.40	7.45	7.40
CD (0.05)	0.40	0.30	0.17	0.50

during six month mould infection was detected only in candy from somaclone CHP 282 (1.00 X 10^{-2}) (Table 37).

4.4.3.3.3 Yeast population

Yeast population was not detected in ginger candy samples in initial as well as at two and four months after storage. During six months after storage only CHP 99 showed yeast population of 1.00 X 10^{-3} among the different samples (Table 37)

4.4.3.4 Sensory evaluation

The prepared ginger candy was subjected to sensory evaluation and the best somaclones for ginger candy preparation were identified based on the sensory scores (Appendix III). Total score for ginger candy from different somaclones ranged from 65.39 to 44.87. Candy from somaclone SE 8642 was identified as the best sample as the score for appearance, colour, flavor, texture, odour, taste, after tatse, overall acceptability and total score was highest (65.39) compared to other soamclones, followed by C 8626 (65.02) and SE 8683 (60.98). Candy from C 78284 was considered the least preferred since its score for appearance, colour, flavor, texture, odour, taste, after tatse, and overall acceptability contributing to total score was the lowest (44.87). Other acceptable somaclones for candy are SE 8626, SE 86102, CHP 282 and Aswathy.

Sensory score of ginger candy from different somaclones showed a declining trend during storage. After two months of storage, C 8626 recorded the highest total score of 62.21 followed by SE 8642 (62.05), SE 8683 (59.61), SE 8626 (56.17) and CHP 99 (51.37). Minimum value was observed in C 78284 with total score of 43.65.

Among the samples, C 8626 had maximum total score (61.20) after 4 months of storage, followed by SE 8642 (59.20), SE 8683 (58.74) and SE 8626 (54.03). Minimum total score was recorded by C 78284 (42.85). Candy from somaclones C 8626, SE 8642, SE 8683 and SE 8626 are under acceptable limits based on the score, after four months of storage.

Table 37. Microbial population of ginger candy in stogae

ND – Not Detected

M – Months of storage

Genotypes	Bacteria x 10^{-5}				Mould x 10^{-2}				Yeast x 10^{-3}			
SE 8626	0 M	2M	4M	6M	0 M	2M	4M	6M	0 M	2M	4M	6M
SE 8683	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
C 8626	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
CHP 118	ND	ND	ND	3.20	ND	ND	ND	ND	ND	ND	ND	ND
C 78284	ND	ND	ND	3.03	ND	ND	ND	ND	ND	ND	ND	ND
SE 86102	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
SE 8642	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
C 8632	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
CHP 99	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.00
CHP 282	ND	ND	ND	3.00	ND	ND	ND	1.00	ND	ND	ND	ND
Aswathy	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

After six months of storage, C 8626 obtained maximum total score (58.53) followed by SE 8642 (58.28).Minimum total score was recorded by C 8632 (41.29). Somaclones SE 8626 and SE 8683 are others under acceptable limits based on the score recording more than 50.

4.4.4. STABILITY OF QUALITY PARAMETERS OF GINGER FLAKES DURING STORAGE

4.4.4.1 Physical characteristics

The physical characters like moisture and colour of ginger flakes were observed immediately after preparation and during storage.

4.4.4.1.1 Moisture content

The moisture content of ginger flakes after preparation ranged from 6.00 to 7.94 % and highest value was recorded for flakes from C 8632 (7.94 %) followed by SE 86102 (7.40 %), SE 8626 (7.37 %), CHP 118 (7.10 %) and Aswathy (7.05 %) (Table 38). Minimum moisture content (6.00 %) was observed in SE 8683, C 8626 and SE 8642.

The moisture content of ginger flakes showed an increasing trend during storage irrespective of the material used for preparation. At 2 MAS moisture content of the product ranged from 6.01 to 8.35 %. The flakes from C 8632 recorded highest value (8.35 %) and those from SE 8683, C 8626, C 78284, SE 8642 and CHP 282 recorded moisture content below six percentage. Minimum moisture content (6.01 %) was observed in CHP 282.

At 4 MAS, the moisture content of samples ranged from 6.55 to 8.65 %. Highest moisture content was observed in C 8632 (8.65 %) followed by SE 86102 (8.05 %) and SE 8626 (8.00 %). Minimum moisture content was observed in CHP 282 (6.81 %)

After storage for six months, the moisture content of ginger flakes increased and it ranged from 6.79 to 9.10 %. Minimum moisture content was observed in somaclones SE 8683 (6.79 %) and maximum in C 8632 (9.10 %)

followed by flakes from SE 86102 (8.10 %), SE 86826 (8.00 %) and CHP 118 (8.00 %).

4.4.4.1.2 Colour

Colour of ginger flakes was assessed and it was found that flakes from different somaclones and variety had colour variations (Table 39). SE 8626 exhibited Pale Yellow (158C), SE 8683, C 8626 and CHP 118 had Yellowish White (158 C), C 78284 and Aswathy showed Pale Yellow (20 D), SE 8642 wasYellowish White (158 D), SE 86102 showed Pale Yellow (158 B) and C 8632 and CHP 282 with Pale Yellow (158 D).

There was no notable change in the colour of ginger flakes from different somaclones during 2 MAS.

At 4 MAS also, there was no notable colour change in ginger candy from different somaclones except C 78284 which showed a colour change from Pale Yellow (20 D) to Pale Yellow (20 C).

During 6 MAS, there was no notable colour change in ginger flakes from different somaclones and C 78284 showed Pale Yellow (20 C) colour during this stage.

4.4.4.2 Biochemical parameters

4.4.4.2.1 *pH*

Initial pH content of ginger flakes prepared from different somaclones and variety had pH ranging from 3.90 to 5.58, with the maximum in somaclone SE 8626 (5.58) followed by SE 8642 (4.55). The minimum value for pH was observed in Aswathy (3.90) (Table 40).

When stored for two months, pH content of ginger flakes from somaclones and variety showed an increasing trend with values ranging from 4.11 to 5.79. The maximum pH was observed in somaclone SE 8642 (5.10). The minimum value for pH was observed in C 78284 (4.50).

pH content of ginger flakes from different somaclones at 4 MAS, showed an increasing trend with values ranging from 4.20 to 6.05. The maximum pH was

Table 39. Colour description of ginger flakes in storage

Genotypes	Intial	2 MAS	4 MAS	6 MAS
SE 8626	Pale Yellow (158A)	Pale Yellow (158A)	Pale Yellow (158A)	Pale Yellow (158A)
SE 8683	Yellowish White (158C)	Yellowish White (158C)	Yellowish White (158C)	Yellowish White (158C)
C 8626	Yellowish White (158C)	Yellowish White (158C)	Yellowish White (158C)	Yellowish White (158C)
CHP 118	Yellowish White (158C)	Yellowish White (158C)	Yellowish White (158C)	Yellowish White (158C)
C 78284	Pale Yellow (20D)	Pale Yellow (20D)	Pale Yellow (20C)	Pale Yellow (20C)
SE 86102	Pale Yellow (158B)	Pale Yellow (158B)	Pale Yellow (158B)	Pale Yellow (158B)
SE 8642	Yellowish White (158D)	Yellowish White (158D)	Yellowish White (158D)	YellowishWhite (158D)
C 8632	Pale Yellow (158B)	Pale Yellow (158B)	Pale Yellow (158B)	Pale Yellow (158B)
CHP 99	Yellowish White (158A)	Yellowish White (158A)	Yellowish White (158A)	Yellowish White (158A)
CHP 282	Pale Yellow (158D)	Pale Yellow (158D)	Pale Yellow (158D)	Pale Yellow (158D)
Aswathy	Pale Yellow (20D)	Pale Yellow (20D)	Pale Yellow (20D)	Pale Yellow (20D)

MAS- Months After Storage

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registered in somaclone SE 8626 with a value of 6.05 and was followed by SE 8642 (5.70) and CHP 282 (5.58). The minimum value for pH was observed in C 78284 (4.50).

At 6 MAS, pH content of ginger flakes ranged from 4.80 to 6.21. The maximum pH was registered in somaclone SE 8626 with a value of 6.21 and was followed by CHP 118 (5.95) and C 78284 (5.80).The minimum value for pH was observed in the check Aswathy (4.80).

4.4.4.2.2 *Titratable acidity*

Titratable acidity observed for ginger flakes from different somaclones including check variety ranged between 1.10 to 1.58 %, with the maximum in SE 8610 and SE 8642 with a value of 1.58 followed by Aswathy (1.41 %). The minimum value for titratable acidity (1.10 %) was observed C 8632 (Table 41).

After two months of storage, titratable acidity of ginger flakes showed a decreasing trend with values ranging from 1.07 to 1.24 %. The maximum pH was observed in SE 8642 (1.24 %) which was on par with C 78284 and SE 86102 with 1.23 % titratable acidity, followed by check variety Aswathy (1.21 %). The minimum titratable acidity was observed in somaclones C 8626 (1.01 %) and CHP 118 (1.07 %).

Titratable acidity of ginger flakes at 4 MAS showed values ranging from 0.23 to 0.80 %. The maximum titratable acidity was registered in SE 8683 with 0.80 % which was on par with SE 8626 with 0.79 % titratable acidity. The minimum value for pH was observed in CHP 282 (0.23 %).

At 6 MAS, titratable acidity of ginger flakes ranged from 0.31 to 0.61%. The maximum titratable acidity (0.61 %) was registered in somaclone SE 86102 and was on par with SE 8642 (0.60 %) followed by C 8626 (0.49 %), CHP 99 and Aswathy with a value of 0.50 % titratable acidity. The minimum value was observed in C 8632 (0.31 %).

Table 40. Effect of storage on pH of ginger flakes

Genotypes	pH			
	Initial	2 MAS	4 MAS	6 MAS
SE 8626	5.58	5.79	6.05	6.21
SE 8683	4.16	4.79	4.90	5.15
C 8626	4.00	4.51	4.70	5.00
CHP 118	4.36	4.63	4.85	5.95
C 78284	4.00	4.50	4.50	5.80
SE 86102	4.12	5.01	4.95	5.26
SE 8642	4.55	5.10	5.70	6.00
C 8632	4.23	4.30	4.60	5.00
CHP 99	3.93	4.11	4.20	4.94
CHP 282	4.00	4.21	5.58	6.06
Aswathy	3.90	4.50	4.65	4.80
CD (0.05)	0.14	0.03	0.21	0.29

Table 41. Effect of storage on titratable acidity (%) of ginger flakes

Genotypes	Titratable acidity (%)			
	Initial	2 MAS	4 MAS	6 MAS
SE 8626	1.21	1.15	0.79	0.38
SE 8683	1.11	1.11	0.80	0.40
C 8626	1.30	1.01	0.66	0.49
CHP 118	1.40	1.07	0.75	0.60
C 78284	1.30	1.23	0.42	0.41
SE 86102	1.58	1.23	0.73	0.61
SE 8642	1.58	1.24	0.74	0.60
C 8632	1.10	1.15	0.31	0.31
CHP 99	1.4	1.16	0.34	0.50
CHP 282	1.4	1.15	0.23	0.41
Aswathy	1.41	1.21	0.49	0.50
CD (0.05)	0.10	0.01	0.02	0.03

4.4.4.3 Enumeration of microbial flora

4.4.4.3.1 Bacterial population

In ginger flakes, no bacterial growth was detected in any of the somaclones immediately after preparation and also at 2 and 4 MAS. However it was found that the somaclones CHP 282 (4.20×10^{-5}) and CHP 99 (5.11×10^{-5}) after 6 months of storage, had bacterial population (Table 42).

4.4.4.3.2 Mould population

No mould growth was detected in ginger flakes prepared from different somaclones initial to final period of storage (Table 42).

4.4.4.3.3 Yeast population

No yeast growth was detected in ginger flakes of different somaclones from initial to final period of storage study (Table 42).

4.4.4.4 Sensory evaluation

The prepared ginger flakes was subjected to sensory evaluation by a panel of 15 judges using nine point hedonic scale and the best somaclones for ginger candy preparation were identified based on the sensory scores (Appendix III). Total score for ginger flakes from different somaclones at initial stage ranged from 43.90 to 64.14. Flakes from somaclone SE 8683 was identified as the best as score for appearance, colour, flavor, texture, odour, taste, after tatse, overall acceptability and total score was highest (64.14) compared to other somaclones, followed by SE 8642 (63.26) and C 8626 (61.80). Flakes from CHP 118 was considered the least preferred since its score for appearance, colour, flavor, texture, odour, taste, after tatse, and overall acceptability contributing to total score, was the lowest (43.90). Other acceptable genotypes are SE 8626, CHP 282 and Aswathy.

Sensory score of ginger flakes from different somaclones showed a declining trend during storage. After two months of storage, SE 8683 recorded the highest total score of 63.29 followed by SE 8642 (61.78) and C 8626 (61.01).

Table 42. Microbial population of ginger flakes in storage

ND – Not Detected

M – Months of storage

Genotypes	Bacteria x 10^{-5}				Mould x 10^{-2}				Yeast x 10^{-3}			
SE 8626	0 M	2M	4M	6M	0 M	2M	4M	6M	0 M	2M	4M	6M
SE 8683	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
C 8626	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
CHP 118	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
C 78284	ND	ND	ND	3.20	ND	ND	ND	ND	ND	ND	ND	ND
SE 86102	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
SE 8642	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
C 8632	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
CHP 99	ND	ND	ND	5.11	ND	ND	ND	ND	ND	ND	ND	ND
CHP 282	ND	ND	ND	4.20	ND	ND	ND	ND	ND	ND	ND	ND
Aswathy	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

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Somaclones SE 8626 and CHP 99 recorded total score more than 50 compared to others. Minimum score was observed in CHP 118 with total score of 42.77.

Among the samples, SE 8683 recorded the highest total score of 62.27 followed by SE 8642 (60.85) and C 8626 (60.16). Minimum score was observed in CHP 118 with total score of 41.88. Somaclones SE 8626 and CHP 99 are others under acceptable limits based on the score, after four months of storage.

After six months of storage, SE 8683 recorded the highest total score of 58.66 followed by SE 8642 (58.40), C 8626 (58.12) and SE 8626 (51.86). Minimum total score was recorded by CHP 118 (40.16).

4.4.5. STABILITY OF QUALITY PARAMETERS OF GINGER POWDER DURING STORAGE

Ginger powder prepared from different somaclones and variety Aswathy was assessed for its physical and biochemical parameters

4.4.5.1 Physical characteristics

4.4.5.1.1 Moisture content

Initial moisture content of ginger powder ranged from 6.00 to 9.05 %, with somaclone CHP 282 recording highest value (9.05 %) followed by SE 86102 (7.74 %). Minimum moisture content was observed in SE 8626 (5.90 %), C 8626 and SE 8642 with a value of (6.00%) (Table 43).

Moisture content of ginger powder from all somaclones and variety Aswathy showed an increasing trend during storage. At 2 MAS moisture content of the product ranged from 6.03 to 9.10 %. The somaclone CHP 282 recording highest value (9.10 %) followed by CHP 99 (7.90 %). Somaclones SE 8626, SE 8683, C 8626, C 78284 and CHP 282 recorded moisture content below six percentage. Minimum moisture content (6.03 %) was observed in SE 8683.

During 4 MAS, the moisture content of samples ranged from 6.80 to 9.53 %. Highest moisture content was observed in CHP 282 (9.53 %) followed by SE 8626, CHP 118, SE 86102, SE 8642 and CHP 99. Minimum moisture content was observed in SE 8683 and C 8626 with a value of 6.80%.

Table 43. Effect of storage on moisture content (%) of ginger powder

Genotypes	Moisture content (%)			
	Initial	2 MAS	4 MAS	6 MAS
SE 8626	5.90	6.35	8.15	8.57
SE 8683	6.00	6.03	6.80	7.00
C 8626	6.00	6.35	6.80	7.20
CHP 118	7.13	7.67	7.94	8.37
C 78284	6.32	6.27	7.00	7.65
SE 86102	7.74	7.55	7.94	8.15
SE 8642	7.00	7.26	8.00	8.40
C 8632	7.00	7.34	7.00	8.00
CHP 99	7.28	7.90	8.00	8.69
CHP 282	9.05	9.10	9.53	10.00
Aswathy	7.10	7.38	7.10	7.95
CD (0.05)	0.16	0.22	0.50	0.09

Table 45. Effect of storage on pH of ginger powder

Genotypes	pH			
	Initial	2 MAS	4 MAS	6 MAS
SE 8626	5.53	5.78	5.95	6.21
SE 8683	4.20	4.79	4.80	5.20
C 8626	4.00	4.50	4.70	5.00
CHP 118	4.37	4.61	4.69	5.00
C 78284	4.10	4.51	4.48	5.10
SE 86102	4.12	5.01	5.01	5.21
SE 8642	4.60	5.01	5.60	6.00
C 8632	4.21	4.30	4.60	5.00
CHP 99	3.94	4.11	4.22	4.84
CHP 282	4.15	4.21	4.63	5.00
Aswathy	3.95	4.48	4.69	4.95
CD (0.05)	0.22	0.03	0.07	0.11

At 6 MAS, moisture content of ginger powder ranged from 7.00 10.00 %. Highest moisture content was observed in somaclones CHP 282 (10.00 %) followed by CHP 99 (8.69 %). Minimum moisture content was in SE 8683 (7.00%).

4.4.5.1.2 Colour

Colour of ginger powder was assessed by using Royal Horticulture Society Colour Chart (Edition V) (Table 44). Initially ginger powder from different somaclones and check variety observed, SE 8626 and CHP 118 exhibited Pale Yellow (158 A), SE 8683 exhibited Pale Yellow (12 D), C 8626 showed Yellowish White (158 C), C 78284 and CHP 282 showed Pale Yellow (158 B), SE 8642 with Yellowish White (158 D), CHP 99 with Pale Yellow (11 D) and Aswathy with Pale Yellow (8 D).

There was no notable colour change in ginger powder of different treatments during two months after storage except C8632 which exhibited a slight colour change from Pale Yellow (158 D) to Pale Yellow (11 D).

At 4 MAS, there was a colour change in SE 8626 from Pale Yellow (158 A) to Pale Yellow (158 B) and Aswathy from Pale Yellow (8 D) to Pale Yellow (12D). Whereas all others remained the same as observed at 2 MAS.

During 6 MAS, there was no notable colour change in the somaclone and check variety Aswathy and they exhibited same hues as observed at 4 MAS.

4.4.5.2 Biochemical parameters

4.4.5.2.1 *pH*

The pH content of ginger powder from different somaclones was determined soon after the preparation and it was found to vary from 3.94 to 5.53, with the maximum in somaclone SE 8626 (5.53) which was followed by SE 8642 (4.60). The minimum value for pH was observed in somaclone CHP 99 (3.94) (Table 45).

During 2 MAS, pH content of ginger powder from different somaclones including check showed an increasing trend with values ranging from 4.11 to

Table 44. Colour description of ginger powder in storage **MAS- Months After Storage**

Genotypes	Intial	2 MAS	4 MAS	6 MAS
SE 8626	Pale Yellow (158A)	Pale Yellow (158A)	Pale Yellow (158B)	Pale Yellow (158B)
SE 8683	Pale Yellow (12D)	Pale Yellow (12D)	Pale Yellow (12D)	Pale Yellow (12D)
C 8626	Yellowish White (158C)	Yellowish White (158C)	Yellowish White (158C)	Yellowish White (158C)
CHP 118	Pale Yellow (158A)	Pale Yellow (158A)	Pale Yellow (158A)	Pale Yellow (158A)
C 78284	Pale Yellow (158B)	Pale Yellow (158B)	Pale Yellow (158B)	Pale Yellow (158B)
SE 86102	Pale Yellow (158B)	Pale Yellow (158B)	Pale Yellow (158B)	Pale Yellow (158B)
SE 8642	Yellowish White (158D)	Yellowish White (158D)	Yellowish White (158D)	Yellowish White (158D)
C 8632	Pale Yellow (158B)	Pale Yellow (11D)	Pale Yellow (11D)	Pale Yellow (11D)
CHP 99	Pale Yellow (11D)	Pale Yellow (11D)	Pale Yellow (11D)	Pale Yellow (11D)
CHP 282	Pale Yellow (158B)	Pale Yellow (158B)	Pale Yellow (158B)	Pale Yellow (158B)
Aswathy	Pale Yellow (8D)	Pale Yellow (8D)	Pale Yellow (12D)	Pale Yellow (12D)

5.78. The maximum pH was observed in somaclone SE 8626 with a value of 5.78 and was followed by SE 8642 (5.10). The minimum value for pH was observed in somaclone CHP 99 (4.11).

pH content of ginger powder at 4 MAS showed an increasing trend with values ranging from 4.22 to 5.95. The maximum pH was registered in somaclone SE 8626 with a value of 5.95 and was followed by SE 8642 (5.10). The minimum value for pH was observed in CHP 99 (4.11).

At 6 MAS, pH content of ginger powder ranged from 4.84 to 6.20. The maximum pH was registered in somaclone SE 8626 with a value of 6.20 and was followed by SE 8642 (6.00). The minimum value for pH was observed in the check CHP 99 (4.84).

4.4.5.2.2 *Titratable acidity*

Initial titratable acidity observed for ginger powder from different somaclones including check variety ranged between 1.48 to 2.06 %, with the maximum in somaclones C 8626 (2.06 %) which was on par with CHP 282 (2.05 %) and Aswathy (2.04 %). The minimum value for titratable acidity was observed CHP 99 (1.50 %) followed by CHP 118 (1.53 %) (Table 46).

During 2 MAS, titratable acidity of ginger flakes showed a decresing trend with values ranging from 1.00 to 1.38 %. The maximum pH was observed in Aswathy (1.38 %) which was on par with CHP 282 (1.32 %) and also CHP 118 and SE 8626 with 1.31 % titratable acidity. The minimum titratable acidity was observed in somaclones C 8632 (1.00 %).

Titratable acidity of ginger powder at 4 MAS showed values ranging from 0.69 to 1.01 %. The maximum titratable acidity was registered in C 8632 with 1.01 % which was on par with SE 8683 and SE 8642 (1.00 %). The minimum value for pH was observed in Aswathy (0.69 %).

At 6 MAS, titratable acidity of ginger powder ranged from 0.10 to 0.80%. The maximum titratable acidity (0.80 %) was registered in somaclones SE 8626 and CHP 282 (0.80 %) followed by SE 8683 and CHP 118 (0.79 %). The minimum value was observed in Aswathy (0.10 %).

Table 46. Effect of storage on titratable acidity (%) of ginger powder

Genotypes	Titratable acidity (%)			
	Initial	2 MAS	4 MAS	6 MAS
SE 8626	2.00	1.31	0.79	0.80
SE 8683	2.06	1.20	1.00	0.79
C 8626	2.10	1.20	0.70	0.61
CHP 118	1.53	1.31	0.84	0.79
C 78284	1.48	1.11	0.91	0.71
SE 86102	1.69	1.22	0.81	0.51
SE 8642	1.61	1.05	1.00	0.35
C 8632	1.66	1.00	1.01	0.45
CHP 99	1.50	1.06	0.70	0.58
CHP 282	2.05	1.32	0.90	0.80
Aswathy	2.04	1.38	0.69	0.10
CD (0.05)	0.07	0.11	0.04	0.07

4.4.5.3 Enumeration of microbial flora

4.4.5.3.1 Bacterial population

In ginger powder, no bacterial growth was detected in any of the somaclones immediately after preparation and also at 2 and 4 MAS. However it was found in the somaclones SE 8642 (3.00×10^{-5}) and CHP 282 (4.30×10^{-5}) after 6 months of storage (Table 47).

4.4.5.3.2 Mould population

No mould growth was detected in ginger powder of different somaclones from initial to final period of storage study (Table 47).

4.4.5.3.2 Yeast population

No yeast growth was detected in ginger powder of different somaclones from initial to final period of storage study (Table 47).

Table 47. Microbial population of ginger powder in storage

ND – Not Detected

M- Months of storage

Genotypes	Bacteria x 10^{-5}				Mould x 10^{-2}				Yeast x 10^{-3}			
SE 8626	0 M	2M	4M	6M	0 M	2M	4M	6M	0 M	2M	4M	6M
SE 8683	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
C 8626	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
CHP 118	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
C 78284	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
SE 86102	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
SE 8642	ND	ND	ND	3.00	ND	ND	ND	ND	ND	ND	ND	ND
C 8632	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
CHP 99	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
CHP 282	ND	ND	ND	4.30	ND	ND	ND	ND	ND	ND	ND	ND
Aswathy	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

4.4.5.4 Sensory evaluation

The prepared ginger powder was subjected to sensory evaluation by a panel of 15 judges using nine point hedonic scale and the best somaclones for ginger candy preparation were identified based on the sensory scores (Appendix III). Total score for ginger powder from different somaclones at initial stage ranged from 43.94 to 65.28. Powder from somaclone SE 8683 was identified as the best sample as its score for appearance, colour, flavor, texture, odour, taste, after tatse, overall acceptability and total score was the highest (65.28) compared to other somaclones, followed by SE 8642 (63.76), C 8632 (62.76) and C 8626 (61.13). Powder from CHP 118 was considered the least preferred since its score for appearance, colour, flavor, texture, odour, taste, after taste, and overall acceptability contributing to total score, was the lowest (43.94). Other acceptable somaclones are SE 8626, CHP 99 and Aswathy.

Sensory score of ginger powder from different somaclones showed a declining trend during storage. After two months of storage, SE 8683 recorded the highest total score of 63.30 followed by SE 8642 (62.71), C 8632 (61.63) and C 8626 (60.77). Somaclones SE 8626 and CHP 99 recorded total score more than 50 compared to others. Minimum score was observed in CHP 118 with total score of 42.76.

Among the samples, SE 8642 recorded the highest total score of 61.51 followed by SE 8683 (59.93), C 8626 (59.57) and C 8632 (57.82). Minimum score was observed in C 78284 with total score of 43.25 after four months of storage. Somaclones SE 8642, SE 8683, C 8626 and C 8632 are under acceptable limits based on the score, after four months of storage.

After six months of storage, SE 8683 recorded the highest total score of 58.44 followed by SE 8642 (58.17) and C 8626 (58.02).Minimum total score was recorded by CHP 282 (41.32). Somaclones SE 8626, SE 8683, C 8626, SE 8642 and C 8632 are under acceptable limits based on the score, after six months of storage.

DISCUSSION

5. DISCUSSION

Ginger is one of the most widely cultivated and used spice around the globe. India is a major ginger growing country contributing 35 per cent of global production. Kerala has a prominent position as a ginger growing state and produces Cochin and Calicut ginger renowned for their intrinsic qualities. In spite of these, significant strides could not make in the processing sector unlike small growers like Australia and Fiji which are the major exporters of value added products from ginger. This is primarily due to lack of varieties having good processing qualities. Somaclonal variation act as a major source of variability for crop improvement.

Induction of variability through induced polyploidy attempted at Department of Plantation Crops & Spices, College Of Horticulture, Vellanikkara, has succeeded in the development of two autotetraploids (Sheeba, 1996) with desirable quality attributes like low fibre content and high aromatic oil and oleoresin but susceptible to the diseases which restricts their commercial utility (Shankar, 2003). In order to increase the spectrum of variability in these tetraploids, induction of variation *in vitro* through indirect methods of regeneration and mutagenesis was attempted as part of DBT funded project from 2006 to 2010. 'This has resulted in development of potential variants which on preliminary evaluation revealed wide variability in quality Kurian (2010) and Dev (2013).

The present study entitled "Screening ginger (*Zingiber officinale* Rosc.) genotypes under different growing conditions and for value addition." was taken up in this background at College of Horticulture, Vellanikkara during 2015-18 to evaluate somaclones for quality attributes, suitability for growing under different growing conditions and for value addition. These somaclones were developed through indirect organogenesis and indirect embryogenesis with and without mutagenesis from three cultivars (two induced polyploids Z-0-78, Z-0-86 and diploid cultivar Himachal Pradesh), at the Department of Plantation Crops & Spices, College Of Horticulture, Vellanikkara.

5.1 SCREENING GINGER GENOTYPES FOR YIELD AND QUALITY

5.1.1 Experimental material

The somaclones derived through indirect methods of regeneration with and without irradiation from two induced polyploids (Z-0-78 and Z-0-86) and a diploid cultivar Himachal Pradesh form the base material for the study. Among the ten somaclones, five somaclones were derived from Z-0-86, two somaclones from Z-0-78 and three somaclones were from Himachal.

5.1.2 Morphological characters

5.1.2.1 Number of days for sprouting

There was significant difference among the genotypes on the number of days for sprouting. Early sprouting (13.97 days) was observed in Aswathy whereas sprouting was late in CHP 99 (23.67 days). Days for sprouting was more than 20 in C 8626, SE 8642, CHP 282 and CHP 99.

5.1.2.2 Plant height

The plant height increased from two month after planting (MAP) to 6MAP and significant differences were observed among the ginger genotypes. At 2 MAP, plant height among the ginger somaclones ranged between 17.75 cm (C 8626) and 43.76 cm (CHP 118). Variation in plant height among the ginger genotypes was reported by Sangeetha and Subramanian (2015) which ranged from 43.5 cm to 60 cm under Coimbatore conditions. Somaclone CHP 118 recorded maximum plant height of 43.76 cm at 2 month stage and minimum plant height was noted in somaclone C 86 26 (17.75 cm). During 3rd month after planting, maximum plant height (85.03 cm) was recorded by somaclone SE 86 102 and minimum plant height (35.20 cm) was observed for somaclone C 86 26. At 4 MAP, 5 MAP and 6 MAP somaclone SE 86 102 recorded maximum plant heights (92.42, 103.80 and 107.38 respectively). This is in conformity with the studies made by Metali (2016) who observed that the plant height increased rapidly during 4th and 5th month and then declined. Similar variability in plant height of ginger somaclones was reported by Dev (2013), Dhatt *et al.* (2008) in turmeric and Iwo *et al.* (2011) in ginger.

5.1.1.3 Number of tillers per plant

The data pertaining to the number of tillers per plant recorded significant differences among the genotypes (Figure 1). Number of tillers increased with age of plant and reached maximum at 6 MAP. At 4 month stage, number of tillers ranged from 5.97 (CHP 282) to 12.33 (CHP 118). Number of tillers was more than 10 in SE 8683, SE 8626 and CHP 118. At 6 MAP, tiller number was more than 16 in SE 8626 (18.01), CHP 118 (20.33), SE 8642 (17.97) and C 8632 (16.93). This is supported by the findings of Sangeetha and Subramanian (2015), who reported that, increment in tiller number might be due to higher translocation of stored food in the rhizome to the new sprouts along with favourable climatic conditions during the growth period *viz.,* optimum atmospheric and soil temperature and relative humidity. This finding is in concordance with Durgavathi (2011) and Surendrababu *et al.* (2017). Dev (2013) reported variability in number of tillers in ginger somaclones and Shadap *et al.* (2013) reported the better performance of turmeric on number of tillers per clump and number of leaves per clump planted on the month of June.

5.1.1.4 Number of leaves per shoot

Significant difference was observed between somaclones in the number of leaves per shoot. Number of leaves increased with age and reached maximum at 6 MAP. During 4^{th} MAP, somaclone CHP 118 recorded highest number of leaves per shoot with a value of 16.53. During 5^{th} MAP, somaclone CHP 118 recorded highest value (20.33) number of leaves per shoot and was on par with SE 8642 (19.33). At 6 MAP, CHP 118 recorded maximum number of leaves per shoot (28.67) and was on par with SE 8626 (28.33). The number of leaves increased with increase in age and peaked at 6^{th} month. Li *et al.* (2010) claimed that the active phase of vegetative growth of ginger plant is 110-130 days after planting, or around 4^{th} month, a phase when most activities are allocated to plant vegetative

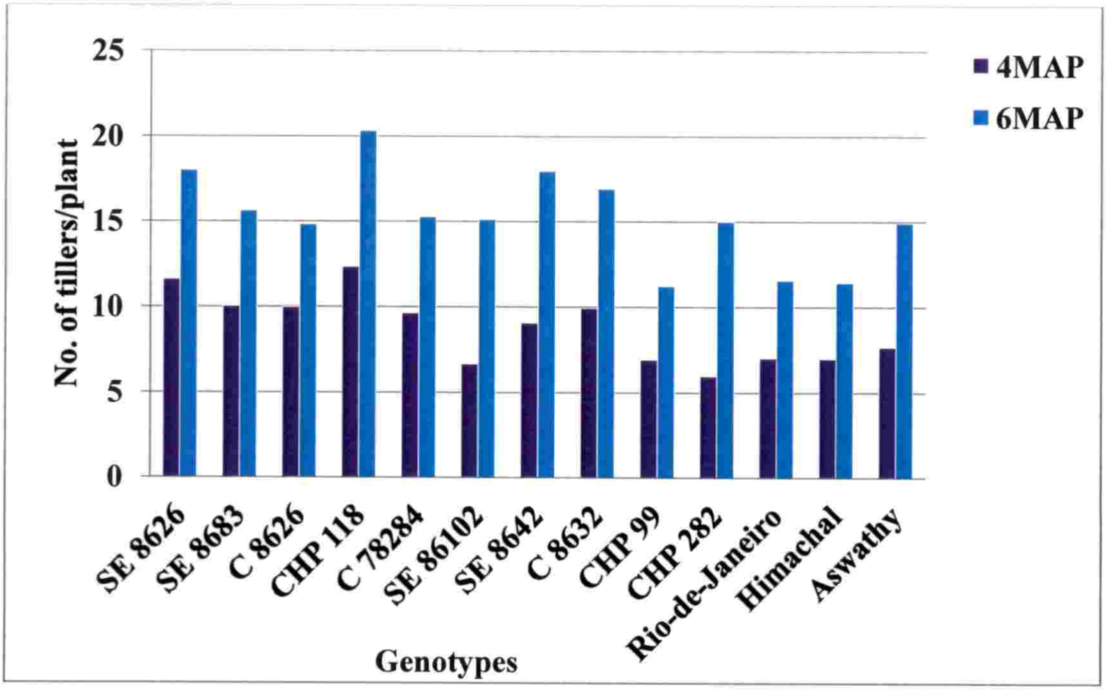

Fig 1. Number of tillers / plant in ginger genotypes

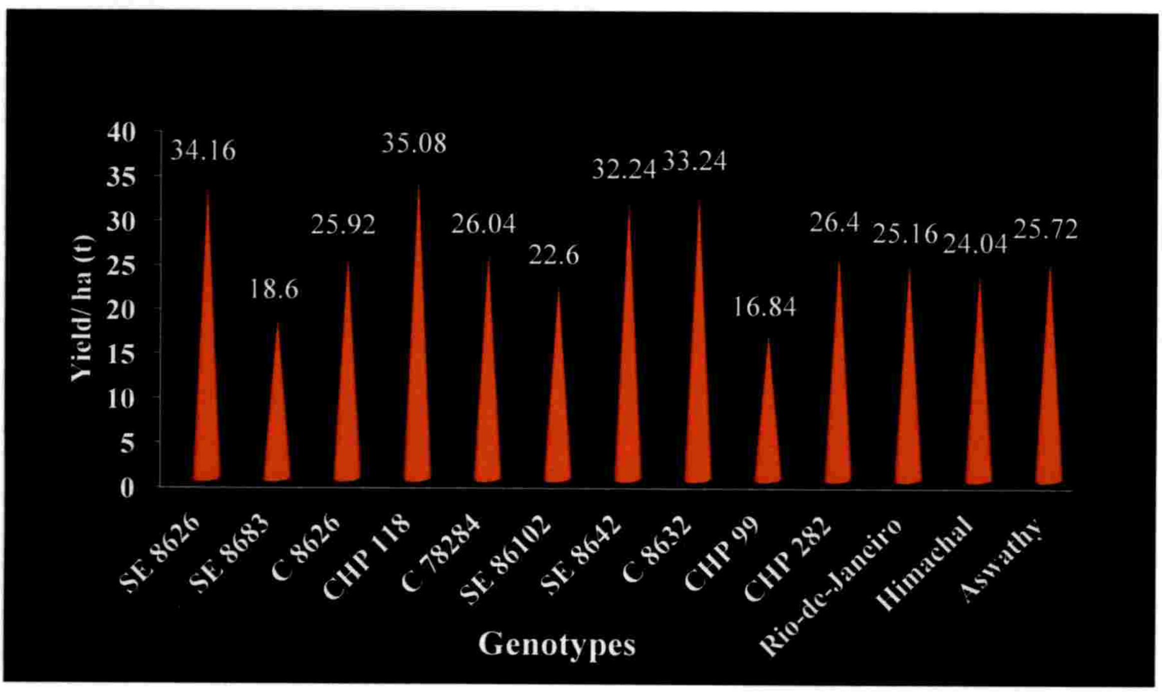

Fig 2. Fresh yield/ha in ginger genotypes

growth. The next phase is the phase of charging the rhizomes. Metali (2016) reported similar result in ginger, as vegetative growth peaked at 4th and 5th month, followed with rhizome development phase.

5.1.1.5 Total number of leaves per plant

The number of leaves per clump is important, as it is a source of carbohydrate production which is utilized for buildup of new cells. This leads to better growth, absorption of nutrients and ultimately increase in production of fresh and dry weight of plants. In the present study, significant difference was observed among the somaclones in the total number of leaves per plant during the (Table 6). At 2 month stage, SE 8626 registered the highest value (21.77) and was on par with CHP 118 (21.03), SE 8642 (20.86), C 8632 (19.06) and SE 8683 (18.76). The lowest value (12.96) was recorded by the somaclone C 78284. During 4th MAP, somaclone CHP 118 recorded highest number of total leaves per plant with a value of 69.82 and was on par with SE 8626 (68.33), SE 8642 (63.89), C 8632 (62.01) and CHP 282 (59.72). At 6 MAP, CHP 118 recorded maximum number of leaves per plant (117.33) and was on par with SE 8626 (108.33), SE 8642 (108.11) and C 8632 (107.33). It was found that there significant difference among the somaclones on the total number of leaves per plant at 4 and 6 MAP. Sangeetha and Subhramanian (2015) reported significant variation with respect to number of leaves among different genotypes with maximum number of leaves in Z O 26 (148.56) at 150 DAP.

5.1.1.6 Leaf area

The leaf area of different somaclones was recorded from two MAP and it was found that there was significant difference among the somaclones on the leaf area during the 2nd to 6th MAP (Table 6). At 2 MAP the highest value (61.86 cm^2) was recorded by the somaclone CHP 118 and lowest value (25.59 cm^2) was for the somaclone SE 8683. During 3rd MAP, the somaclone CHP 118 registered the highest value (65.42 cm^2) and was on par with CHP 282 (63.69 cm^2). During 4th MAP, the somaclone CHP 118 recorded the highest value (72.22 cm^2) and was on par with C 8632 (70.48 cm^2). Leaf area increased from 2 to 4 month stage and later decreased. C86 32 recorded the highest values (62.12 and 49.22 cm^2respectively) for leaf area at 5 and 6 MAP. At 6 month stage, C 8632 and SE 8642 recorded highest leaf area. This might be due to the differences in leaf length and width as the age of the plant advances and due to environmental conditions. Leaf area influences the photosynthetic efficiency of plants. Balakumbahan and Joshua (2017) reported that the leaf area in ginger genotypes under Pechiparai condition varied significantly recording highest total leaf area of 7732.76 cm^2 was recorded in the genotype Z.O- 1 (IISR Varadha) which is on par with Z.O – 4 (7668.06 cm^2).This result is supported by the findings of Surendrababu *et al.* (2017). Channappagoudar *et al.* (2013) reported increase in leaf area from 60-120 days after planting and later a decrease from 180 DAP to harvest in turmeric.

5.1.1.7 Rhizome characters

Significant difference was observed in rhizome characters among somaclones (Table 7, 8 and 9). The number of primary rhizomes was greater than four in CHP 118 (4.83), SE 8626 (4.33) and C 8632 (4.08). The lowest number of primary rhizome was for CHP 99 (2.52). Similarly the number of secondary rhizomes was more than ten (10) in CHP 118 (10.33), SE 8626 (10.06) and C 8632 (10.01). The lowest number of secondary rhizomes (6.00) was for somaclones CHP 99 and CHP 282. The number of tertiary rhizomes was also found maximum for CHP 118 (17.00) and lowest was for control Himachal (7.67). Quaternary rhizomes number was maximum in SE 8626 (12.67) and was on par with CHP 118 (10.67) and SE 8683 (9.33), whereas CHP 99 and C 8632 recorded lowest value of 3.00.

The weight of mother rhizome varied from 5.60 to 11.00 grams with the lowest value of 5.60 g in Rio- de-Janeiro. Higher values for this character was observed in SE 86 42 (11.00 g) and CHP 118 (10.67 g). Weight of primary rhizome significantly differed among the somaclones with higher values in SE 86 42 (15.73 g), SE 8626 (15.07 g), CHP 118 (14.80 g) and C 8632 (14.01 g) and the lowest value in SE 86102 (8.10 g). Secondary rhizome weight was higher in SE 8626 (13.20 g) and SE 86 42 (12.33 g) and the lowest was for CHP 282 (6.33 g).

Higher values for the length of primary rhizomes (> 3cm) were recorded in CHP 118 (3.80 cm), SE 8626 (3.67 cm), SE 8683 (3.43 cm) and C 8632 (3.41 cm), whereas CHP 282 recorded lowest value (2.50 cm) (Table 8). Chongatham *et al.* (2013) reported variations in the length of primary rhizome ranging from 3.01 cm (Suruchi) to 3.53 cm (Varada). Similar to the result of primary rhizome length, SE 8626 (3.57 cm), CHP 118 (3.52 cm) and C 8632 (3.34 cm) recorded higher values for secondary rhizome length also. Internodal length of primary rhizome recorded among the somaclones ranged between 0.70 cm (SE 8683 and Aswathy) to 1.87 cm (CHP 118). Internodal length of secondary rhizome was also found higher in SE 86 26 (1.03 cm), CHP 118 (0.83 cm) and C 8632 (0.87 cm).

Girth of primary rhizome ranged from 6.47 to 9.20 cm (Table 8). Higher value for girth of primary rhizome was recorded in the somaclone SE 8626 (9.20 cm), SE 8642 (9.07 cm), CHP 118 (8.57 cm) and C 8626 (8.57 cm). Rio-de-Janeiro recorded lowest value (6.47 cm) for this character. The somaclone CHP 118 recorded the maximum girth of secondary rhizome (9.07 cm) though it ranged from 5.67 cm to 9.07 cm. The thickness of primary rhizome recorded varied among the somaclones. The maximum thickness of primary finger (2.67 cm) was registered in the somaclone SE 86 26 followed by CHP 282 (2.57 cm) and the lowest value (2.07 cm) was for the somaclone C 8626. The thickness of secondary finger was found to be maximum in the somaclone SE 8626 (2.53 cm) and the lowest value was registered for the somaclone C 78 284 (1.77 cm).

Data on the core thickness of primary and secondary rhizomes revealed highest values in somaclone SE 8626 than other somaclones and check varieties. Superiority of somaclones in yield contributing rhizome characters over parent and check varieties in ginger and turmeric has been reported by Paul (2006), Salvi *et al.* (2002) and Dev (2013). Variability in yield contributing characters in somaclones of spice crops was reported by Chandrappa *et al.* (1996), Sudharshan *et al.* (1997) in Cardamom and Sanchu (2000) in black pepper somaclones.

5.1.1.8 Yield Characters

Yield of any crop largely depends on the vigour of the plant as indicated by various growth parameters like plant height, number of leaves, number of tillers, rhizome characters *etc*. Better growth is normally reflected through higher yield and the growth is governed by the genetic constituent of the variety and environmental condition under which the crop is raised. When different varieties are grown under identical conditions it is the genetic factor that expresses the morphological differences.

a. Fresh Yield

Somaclones and check varieties differed significantly in the yield recorded at full maturity stage. The fresh rhizome yield after harvest was more than 250 g in four somaclones *viz*., CHP 118 (274.13 g), SE 8626 (266.67 g), C 8632 (259.67 g) and SE 8642 (251.67 g). The highest yield per plot (8.77 kg) was recorded in CHP 118 followed by SE 86 26 (8.54 kg), C 8632 (8.31 kg) and SE 8642 (8.06 kg). Computed values for yield per hectare was very high (> 30 t/ha) in CHP 118 (35.08 t), SE 86 26 (34.16 t), C 8632 (33.24 t) and SE 8642 (32.24 t) (Figure 2). The result data showed that out of 13 genotypes including somaclones and check varieties, four somaclones yielded very high. The check varieties yielded only 24-25 t/ha in this study. This is in accordance with the study of Resmi and Shylaja (2012), who observed that 30 per cent somaclones found superior to conventionally propagated plants for rhizome characters. In this study, sixty per cent somaclones exhibited superiority in yield over conventionally propagated plants giving a maximum yield increase of 40 per cent. Samsudeen (1996), Shylaja *et al.* (2003), Paul (2006), Sumathi (2007), Kurian (2010) and Shylaja *et al.* (2010) and Kankanawadi (2015) also reported variability in rhizome yield in ginger somaclones. Increasing number of tillers, aerial shoots and leaves on ginger correlated positively with plant yield, namely fresh weight of rhizome and tillers parameters as reported by Devi *et al.* (2015).

b. Driage and dry Yield

Dry recovery or driage of the rhizomes ranged from 13.56 % (CHP 282) as high as 23.18 % (SE 8626). Saratbabu *et al.* (2017) reported that the percentage of dry ginger recovery in ginger genotypes ranged from 18.47 to 26.32 in a study conducted in Karnataka. Driage was more than 20 percentage in two somaclones namely SE 8626 (23.18 %) and SE 8642 (21.20 %). Dry yield per plot was found highest for the somaclone SE 8626 (1.98 kg) followed by CHP 118 (1.73 kg), SE 8642 (1.71 kg) and C 8632 (1.49 kg). Dry yield per hectare was more than 5 tonnes in four somaclones namely SE 8626 (7.92 t), CHP 118 (6.92 t), SE 8642 (6.84 t) and C 8632 (5.96). Dry yield of check varieties was low ranging from 3.50 to 4.40 t/ha and among these, Aswathy yielded highest. The higher yield observed in the somaclones derived from polyploid parent Z -0-86 in the present study can be attributed to the original parent Rio-de-Janeiro. This is supported by the findings of Paul (2006), who reported that the somaclones derived from cultivar Rio-de-Janeiro were high yielding compared to those from cultivar Maran. Kankanawadi (2015) also reported that somaclones of Z-0-86 showed highest mean fresh rhizome yield (22.42 t ha^{-1}) compared to somaclones of Z-0-78 and HP somaclones (15.50 and 17.34 t ha^{-1} respectively). This is in conformity with the findings of Kale (2001) who reported the highest dry ginger yield in Humnabad Local (8.04 t/ha) and the lowest in genotype Haveri (2.99 t/ha). Similar findings were recorded Kuruber (2003) and Chongtham *et al.* (2013).

5.1.1.9 Quality parameters

Quality parameters such as content of volatile oil, oleoresin and crude fibre were analyzed and the data is given in.

a. Volatile oil

Recovery of volatile oil percentage ranged from 2.10 to 3.80 among the somaclones in this study. The somaclone CHP 118 recorded the highest value (3.80 %) for volatile oil followed by SE 8626 (3.30 %) and the lowest value (2.10 %) was registered by the somaclones SE 8683 and C 8626. Volatile oil content of check varieties were fairly high ranging from 2.90 % (Aswathy) to 3.02 % (Rio-de-Janeiro).

b. Oleoresin

Oleoresin percentage ranged from 4.02 % to 6.58 % among the somaclones and check varieties. All the check varieties are having higher content of oleoresin (> 6%), whereas among somaclones, SE 8626, CHP 118 and CHP 282 were found to possess high oleoresin (> 6%) content. Rio-de-Janeiro is a potential cultivar for oleoresin production as already observed by Shankar (2003). The results are in agreement with the findings of Paul (2006) who reported higher oleoresin recovery in somaclones of Rio-de-Janeiro (4.38 to 8.93%) than the somaclones of cultivar Maran (4.31 to 8.49%).

c. Crude Fibre

Content of crude fibre increased with maturity from 5th month to 7th month in all genotypes. Crude fibre content varied from 2.13 % (C 8626) to 4.03% (SE 8626) at five month maturity. Jogi *et al.* (1972) observed variability in crude fibre content in the range of 1.1 to 7.0 per cent among different ginger cultivars. At seven month maturity, the highest crude fiber content (4.89 %) was registered in the somaclone SE 8626 and the lowest value (3.00 %) was for the somaclones SE 8642 and CHP 282. Kankanawadi (2015) reported that on an average, the crude fiber content of seven somaclones at 180 days was 2.08 % and increased to 3.11% at 240 days. According to Sanal *et al.* (2010), though increase in fiber content was noticed up to the last stage of harvesting, maximum rise in the fiber content was observed between 150 to 180 days of planting. Jogi *et al.* (1972) and Ratnambal *et al.* (1987) also reported similar findings in the variation of crude fibre content. The difference in quality parameters can be due to the inherent characters of the varieties (Borthakur, 1992; Yadav *et al.,* 2004). Chongtham *et al.* (2013) stated that agro-climatic condition and cultural practices have a profound influence on determining the quality characters of ginger.

5.1.1.10 Chemoprofiling of ginger genotype by HPLC

Gingerols and shogaols are the two major pungency stimulating non-volatile compounds present in ginger. Apart from pungent activity gingerols and shogaols are also known for their pharmaceutical properties. Among gingerols, 6-gingerol is the most biologically active compound known for its antioxidant, antipyretic, antiseratogenic, antiulcer and cardiodepressant property. With respect to shogaols, 6-shogoal is the most important and it is known for its antiallergic, antioxidant, antiprostaglandin and CNS-depressant property. The variability of gingerols and its related compounds in thirteen ginger somaclones was assessed by HPLC techniques. The study showed that in all somaclones gingerols were the major pungency contributing compounds present in large quantities compared to shogaol. Jiang *et al.* (2006) also reported similar results. Ratio of gingerol to shogaol decides quality of the ginger, and pungency of ginger gradually decreases when the amount of gingerol decreases and shoagaol increases (Zachariah *et al.*, 1993). In the present study, the somaclones showed significant variation among the content of gingerols (Appendix II). (6)- Gingerol, (8) - Gingerol and (10)-Gingerol was found maximum for Rio-de-Janeiro (1.20%, 0.14 % and 0.14 % respectively). Hence the total gingerol content was recorded maximum for Rio-de-Janeiro (1.48 %). Similar results were reported by Chen *et al.* (1986) and Bartley (1995). Kizhakkayil and Sasikumar (2012) screened 46 ginger accessions for non volatile compounds and reported that 6-gingerol content range from 0.36% (Oman) to 3.11% (Angamali) and shogaols content from 0.23 % (Palai) to 1 % (Oman). Chen *et al.* (1986) also reported total gingerol content (6-, 8- and 10-gingerol) of 0.65–0.88% (w/w) in green ginger and 1.10–1.56% (w/w) in dry ginger.

The total shogaol content was registered highest in CHP 282 (0.16 %) followed by Rio-de-Janeiro (0.11 %) and SE 8642 (0.10 %). Present study using HPLC observed meager levels of shogaols in all the somaclones of ginger; supporting the finding of Jolad *et al.* (2005) who also reported low shogaol compounds in ginger oleoresin. Storage of oleoresin can result in chemical conversion of gingerols to less pungent shogaols and this conversion is undesirable with respect to quality because of loss of pungency, development of off flavour and accumulation of non pungent residue.

5.1.1.11 Physiological characters

The chlorophyll index was recorded maximum for Himachal (45.25) followed by CHP 99 (43.58) and the lowest was for the somaclone C 86 26 (36.02) at six month maturity. Chlorophyll index values were higher (>40) in seven somaclones namely SE 8683, CHP 118, SE 8642, CHP 99, CHP 282, Rio-de-Janeiro and Himachal. The photosynthetic rate was recorded maximum for the somaclone SE 8642 (20.13 μmol $m^{-2}sec^{-1}$) followed by CHP 118 (18.80 μmol $m^{-2}sec^{-1}$) and CHP 99 (18.75 μmol $m^{-2}sec^{-1}$) and the lowest was for Rio-de-Janeiro (11.00 μmol $m^{-2}sec^{-1}$) at six month maturity. The transpiration rate was recorded maximum for the somaclone SE 8642 (1.56 μmol $m^{-2}sec^{-1}$) followed by CHP 118 (0.94 μmol $m^{-2}sec^{-1}$) and the lowest was for CHP 99 (0.63 μmol m^{-2} sec^{-1}) at six month maturity. There was no significant difference among somaclones for stoamatal conductance at six month maturity.

5.1.1.12 Pest and disease incidence

Somaclones along with three check varieties were evaluated for natural occurrence of pest and diseases. Shoot borer incidence was more in Aswathy (28.13 %) at 6 MAP. Lowest incidence was noticed in somaclones CHP 282 (3.13 %), SE 8626 (4.79 %), C 8632 (5.21 %), CHP 118, CHP 99 and SE 86102 with 6.25 % incidence. Dev (2013) reported lower shoot borer incidence in ginger somaclones when compared to parents and check varieties, except SEHP 73 with 36.50 % incidence. Paul (2006) reported high shoot borer incidence in ginger somalcones and that the incidence was influenced by seasons. The parent cultivar of SE 8626, C 8632 and SE 86102 was derived from Rio-de-Janeiro. Shankar (2003) reported that the colchicine induced variants of Rio-de-Janeiro showed least incidence of shoot borer compared to other cultivars.

5.2 PERFORMANCE OF GINGER GENOTYPES UNDER DIFFERENT GROWING CONDITIONS

5.2.1 Morphological Characters

Performance of ginger genotypes under different growing conditions were assessed by observing morphological characters and yield attributes for a period of six months from planting. Morphological characters recorded include number of days for sprouting, plant height, number of tillers per plant, number of leaves per shoot, total number of leaves per plant and leaf area.

5.2.1.1 Number of days for sprouting

There was significant difference among the genotypes on the number of days for sprouting. The number of days for sprouting of the genotypes ranged from 13.67 days to 16.25 days under open field condition whereas under rain shelter, early sprouting was at 11.50 days which extended till 15.75 days. Early sprouting was observed in somaclone SEHP 9 (14.51 days) and check variety Aswathy (13.67 days) under open field whereas late sprouting was observed in SE 8681 (16.25 days). In general, under rain shelter condition, early sprouting was observed in all genotypes compared to open field. The somaclone SE 8640 (11.50 days) showed early sprouting in rain shelter whereas SE 86131 and SE 8681 took more number of days for sprouting (15.75 and 15.25 respectively) compared to other somaclones and check variety. Mean values for days to sproutitng under the two growing conditions (open field and rain shelter) indicate earliness in rain shelter condition (13.74 days) compared to open field (15.13 days). Among the different genotypes, Aswathy recorded least number of days for sprouting (13.43 days) followed by SE 8640 (13.50 days) and SEHP 9 (13.75 days) irrespective of the growing conditions. The somaclone SE 86131 and SE 8681showed delayed sprouting compared to others with a value of 15.75 days (Table 15).

Planting in the month of May might have caused significantly lower number of days for sprouting due to conducive environmental conditions. In this study, days for sprouting ranged from 11.50 to 16.25 days indicating early sprouting which may be due to the favorable environmental conditions that prevailed during the planting period. Optimum temperature and Relative Humidity during the month of May are favourable for better sprouting of ginger seeds (Shadap *et al.* 2013). Jyotsna *et al.* (2012) reported that under rainfed condition of Manipur, number of days for sprouting of ginger varieties ranged from 59.9 to 61.8 days, lowest in variety Bhaisey (59.9 days) followed by Gorubothan (59.9 days) and Nadia (61.1 days), whereas, the variety Manipur local took maximum time (61.8 days) for sprouting. According to Surendrababu *et al.* (2017) early sprouting time (21 days) was noticed in the variety Maran followed by Mahima (31days) under shade net condition.

5.2.1.2 Plant height

Plant height was recorded at monthly intervals and genotypes varied significantly for this character (Figure 3 a & b). The data on plant height at 4th and 6th months after planting is furnished in the Figure 3. At 2 MAP, there was no significant difference among the genotypes for plant height under open field condition and it varied from 26.64 cm (SE 8681) to 30.78 cm (SE 8640). Under rain shelter condition, the somaclone SE 8640 showed higher plant height (35.45 cm) followed by SEHP 9 (34.31 cm). The lowest plant height was for the check Aswathy (26.63 cm). Plant height increased with growth stages in all the genotypes. Drastic increase in plant height was observed at 6 month stage in all genoytpes. Plant height was higher in rain shelter condition in all growth stages except 6 months stage, whereas plants were taller in open field than in rain shelter only at 6 months stage.

SE 8640 and SEHP 9 registered higher plant height at 4 month stage in both the growing conditions. Among the growing conditions, plant height at this stage was higher in rain shelter recording 69.81 cm in SE 8640 and 64.85 cm in SEHP 9.

During 6 MAP, plant height was higher in all genotypes under open field than in rain shelter. Plant height was more than 90 cm in SE 8681 and SE 8640

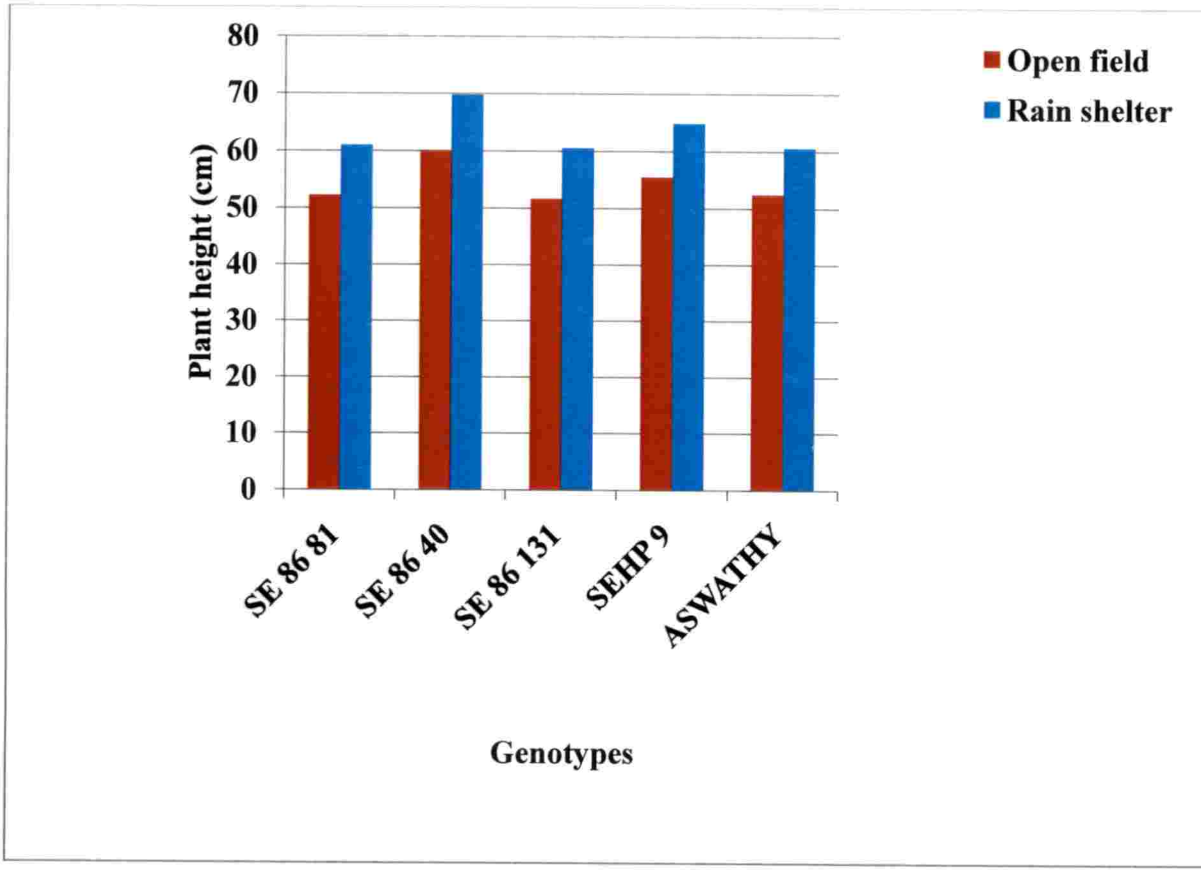

Fig 3a. Plant height 4 months stage under different growing conditions

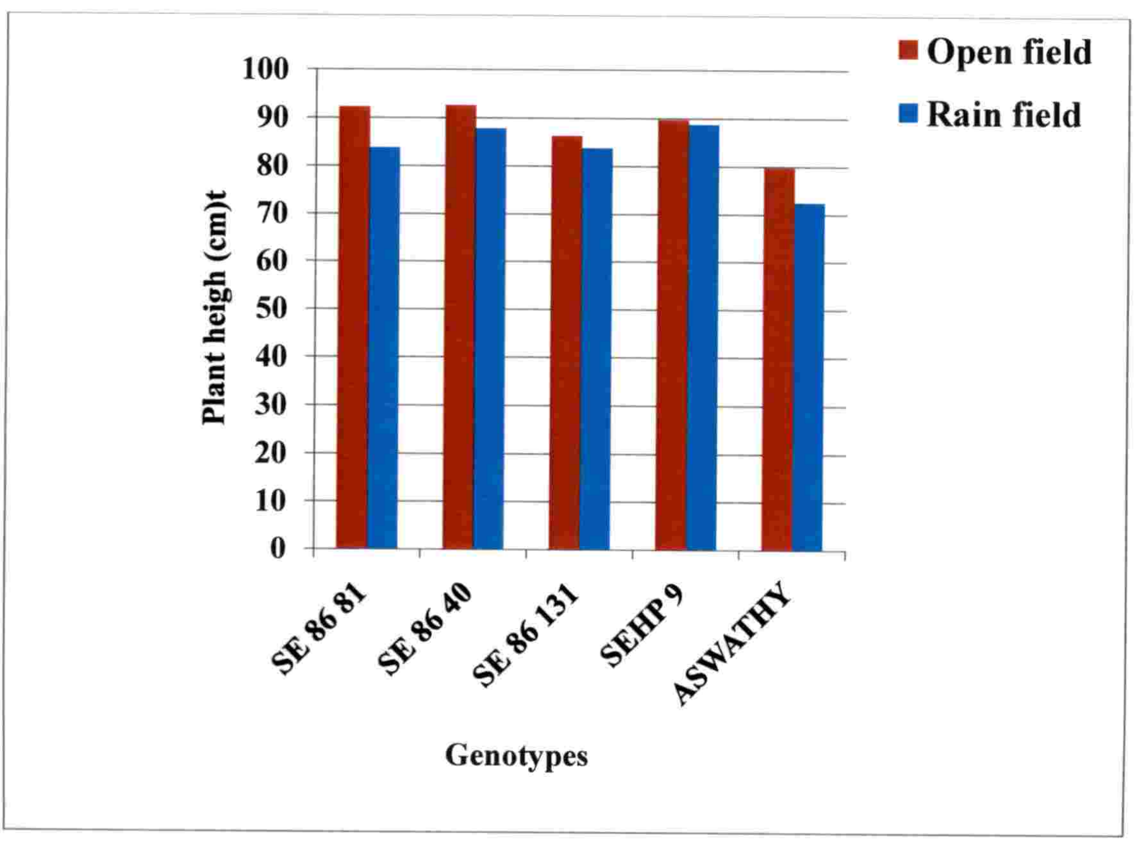

Fig 3b. Plant height at 6 months stage under different growing conditions

under open field condition, whereas Aswathy recorded minimum plant height (79.83 cm). Under rain shelter condition, plant height was more than 80 cm in all the genotypes except Aswathy. The somaclone, SEHP 9 recorded maximum plant height (88.78 cm) followed by SE 8640 (87.84 cm). This might be due to innate character of ginger somaclones which were influenced by controlled climate under both growing conditions. Low light intensity under rain shelter can cause increment in plant height initially.

On comparing the mean values, plant height of somaclones were significantly high under rain shelter (63.37 cm) compared to open field (54.36 cm) at 4 MAP. Among the somaclones, highest plant height recorded by SE 8640 (64.95 cm) was significantly superior to other somaclones and check variety. At 6 MAP, plant height of somaclones were significantly high under open field (88.15 cm) compared to rain shelter (83.36 cm). Among the somaclones, highest plant height was recorded by SE 8640 (90.22 cm) followed by SEHP 9 (89.25 cm) irrespective of the growing conditions (Table 16). Similar result was reported by Bhuiyan *et al.* (2012) and Surendrababu *et al.* (2017) in ginger and Parvej *et al.* 2010 in tomato.

5.2.1.3 Number of tillers per plant

Number of tillers per plant at 4^{th} and 6^{th} months after planting are furnished in the Figure 4 a&b and monthly data on tiller number is shown in Table 17. There was significant difference in the number of tillers produced by the genotypes under different growing conditions. Generally, number of tillers was higher under open field condition in all the genotypes than under rain shelter. With age of the plant, tiller number increased and reached maximum at 6 month stage in all the growing conditions.

The data presented in Figure 4a revealed that tiller number was more than 10 in SEHP 9 and SE 8681 at 4 months stage under open field condition and the lowest was for the check variety Aswathy (7.67). Under rain shelter condition also

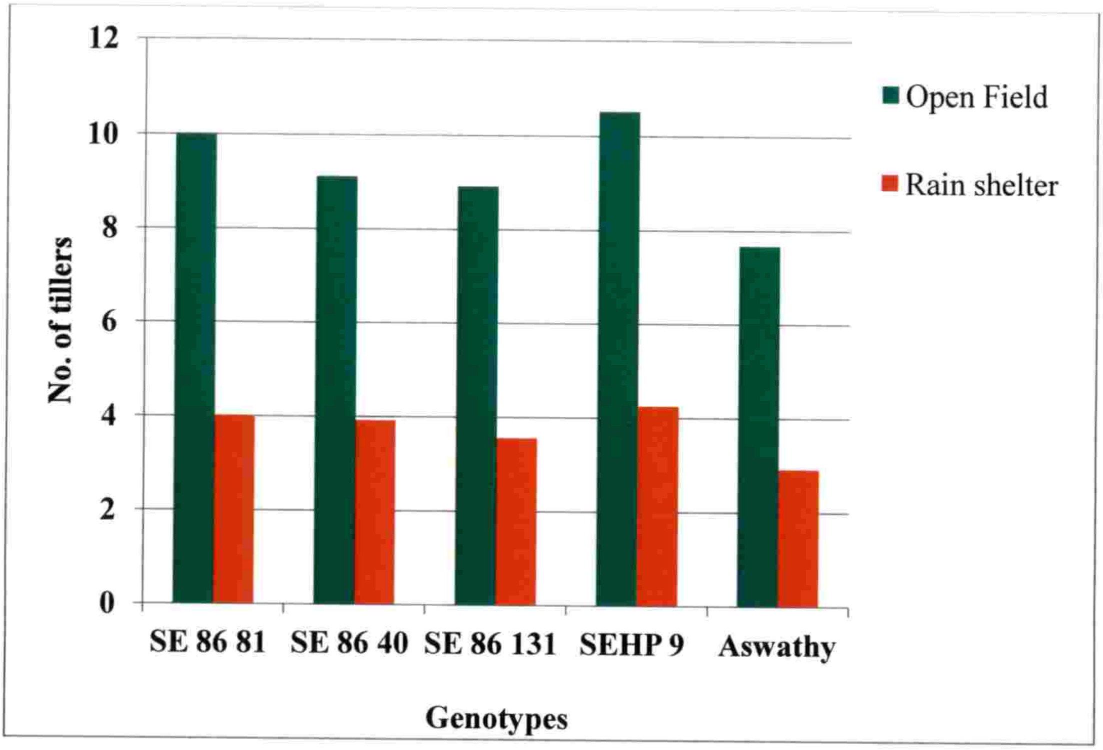

Fig 4a. Number of tillers 4 months stage under different conditions

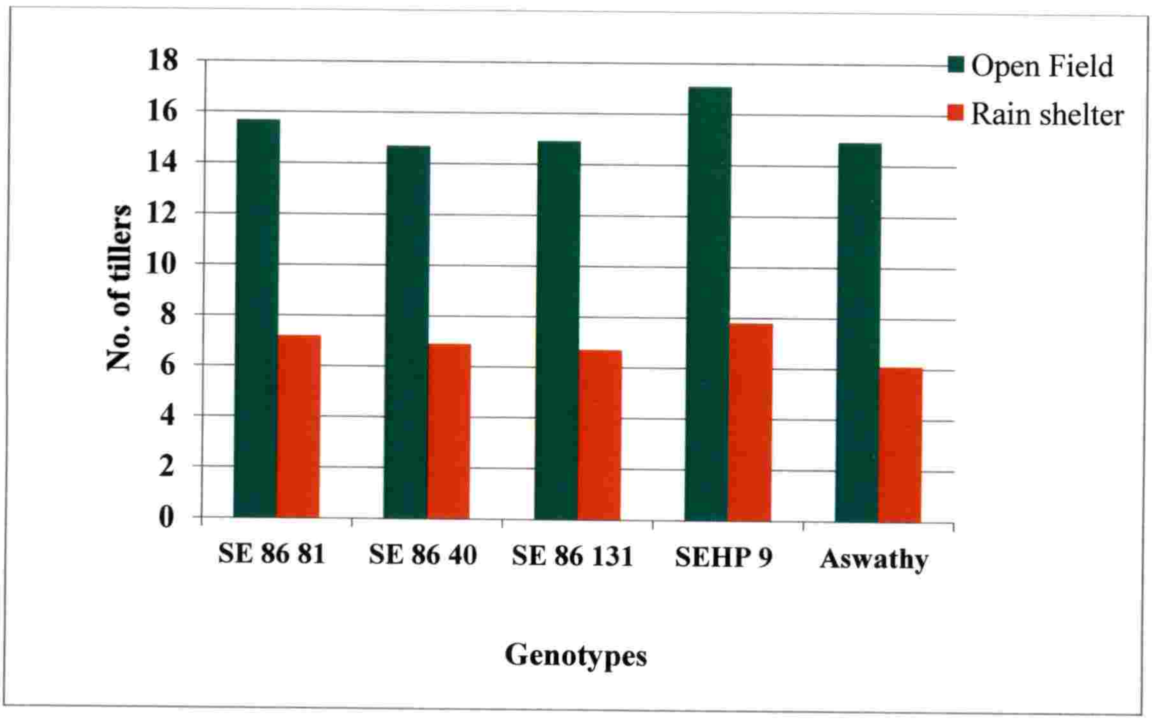

Fig 4b. Number of tillers 6 months stage under different conditions

the same genotypes SEHP 9 and SE 8681 registered a value of more than 4 and the lowest was for Aswathy (2.92).

At 6 MAP, the number of tillers produced by ginger genotypes under open field condition ranged from 14.69 (Aswathy) to 17.09 (SEHP 9). The somaclone, SEHP 9 also recorded highest value for number of tillers per plant (7.80) under rain shelter condition followed by SE 8681 (7.20), SE 8640 (6.90) and SE 86131 (6.70) and the check variety Aswathy recorded the lowest value of 6.10. It is seen that, number of tillers were two times higher in open field grown genotypes than grown in rain shelter conditions.

The mean values for number of tillers in genotypes under two growing conditions indicate significantly higher tiller number under open field condition (9.25) than rain shelter (3.73) at 4 MAP (Table 17c). At 6 month stage also the same trend was observed with higher mean values in open field condition (15.46). Among the genotypes, the somaclone SEHP 9 recorded the highest number of tillers (7.38) at 4 months stage and 12.45 at 6 months stage compared to other somaclones and check, irrespective of the growing conditions. This might be due to genetic constitution of the varieties, genotypic potential and availability of nutrients in the soil, which were influenced by environmental conditions. Low light intensity under rain shelter condition compared to open field (Appendix 1, Table c) may be the reason for low tiller production in rain shelters.

5.2.1.4 Number of leaves per shoot

From the data for the number of leaves per shoot recorded at different months (Table 18). Significant difference was observed genotypes raised under two growing conditions. Number of leaves increased with age of the plant and the values were higher in open field condition in all the genotypes than in rain shelter.

At 4 MAP, the somaclone SE 8640 recorded the highest value (14.10) for number of leaves per shoot followed by SEHP 9 (13.20) and SE 8681 (12.30) and the lowest value (11.25) was for the check variety Aswathy, under open field. Under rain shelter condition also the somaclone SE 8640 (12.10) recorded the maximum value for this character and the lowest was for SE 86131 (8.23) and Aswathy (8.10).

Somaclone SE 8640 recorded highest number of leaves per shoot under open field and rain shelter conditions at 6 month stage with a value of 23.10 and 20.23 respectively. The lowest value for number of leaves per shoot under open field was registered in SE 8681 (19.20) and SE 86 131 (18.27) and in rain shelter lowest number of leaves per plant was for Aswathy (12.45).

Mean number of leaves per shoot under different growing conditions revealed higher values under open field condition at 4 and 6 months stage (12.58 and 20.52 respectively) compared to rain shelter (9.47 and 15.05 respectively). Among the somaclones, SE 8640 recorded the highest number of tillers at 4 months stage (13.10) and 6 months stage (21.65) regardless of the growing conditions (Table 18). Nybe (1978) reported highest number of leaves per tiller in the genotype Valluvanad in a study on morphological variations in twenty five types of ginger. These results are also in close agreement with the findings of Tiwari (2003) for number of leaves per shoot.

5.2.1.5 Total number of leaves per plant

Total number of leaves per plant increased with age of the plant (Table 19). In general, total number of leaves per plant was higher under open field condition than in rain shelter. At 4 MAP, SEHP 9 recorded the highest value for total number of leaves per plant (70.26) which was on par with SE 8640 (67.58) and SE 8681 (66.56) under open field condition and the lowest was in Aswathy (52.31). In rain shelter, also the somaclone SEHP 9 recorded maximum number of leaves per plant (39.30) followed by SE 8640 (36.43) and the lowest value were observed in Aswathy (30.25).

During 6 MAP, the somaclone, SEHP 9 recorded maximum number of leaves per plant (87.47) followed by SE 8640 (87.00) under open field condition and the lowest value was for Aswathy (73.14). The somaclone SE 8640 recorded the highest value for total number of leaves per plant (82.25) under rain shelter condition which was on par with SEHP 9 (78.77) and SE 8681 (77.75). The lowest was for the check variety Aswathy (36.86). Three somaclones namely SEHP 9, SE 8640 and SE 8681 registered higher values for total number of leaves per plant at 4 and 6 months stage under both growing conditions. Significant variation for this character was also observed by Mehra (2012) with values ranging from 79.27 to 134.87. This might be due to genetic constitution of the varieties and genotypic potential of the cultivars. It appears that relatively high light intensity in open condition contributes to more development of leaves in ginger plants grown in open field. Similar results were observed by Singh *et al.* (2000), Kale (2001), Kuruber (2003), Anusuya *et al.* (2004), Dhatt *et al.* (2008), Deshmukh *et al.* (2009), Jadhav *et al.* (2009), Iwo *et al.*(2011), Jyotsna *et al.* (2012), Bhuiyan *et al.* (2012), Rajalakshmi and Umajyothi (2014), and Surendrababu *et al.* (2017) in ginger. Muhammad *et al.* (2012), Naram and Purushotham (2013), Siddalingayya *et al.* (2014) and Virendra *et al.* (2015) in turmeric.

5.2.1.6 Leaf area

The leaf area of different somaclones was recorded at monthly intervals from two months growth stage and significant difference was observed among the somaclones on the leaf area during the 2 to 6 MAP (Table 20).

Four month to six months after planting are considered critical in ginger since the plants are in active growth stage and the data on leaf area at 4 and 6 months are depicted in Figure 5a. At 4 MAP, SE 86131 recorded the highest leaf area of 58.93 cm^2 among the somaclones studied and the lowest was recorded by Aswathy (49.08 cm^2) under open field condition. SEHP 9 recorded the highest value for leaf area (50.41 cm^2) which was found superior to other somaclones and also the check variety Aswathy under rain shelter.

At 6 months stage (Figure 5b), leaf area was found to be the highest for the somaclone SEHP 9 (35.82 cm^2) under open field condition and the lowest was for SE 86131 (24.03 cm^2). In rain shelter, SE 8681 recorded the highest leaf area (31.79 cm^2) and the lowest was for SE 86131 (21.82 cm^2). Results on leaf area

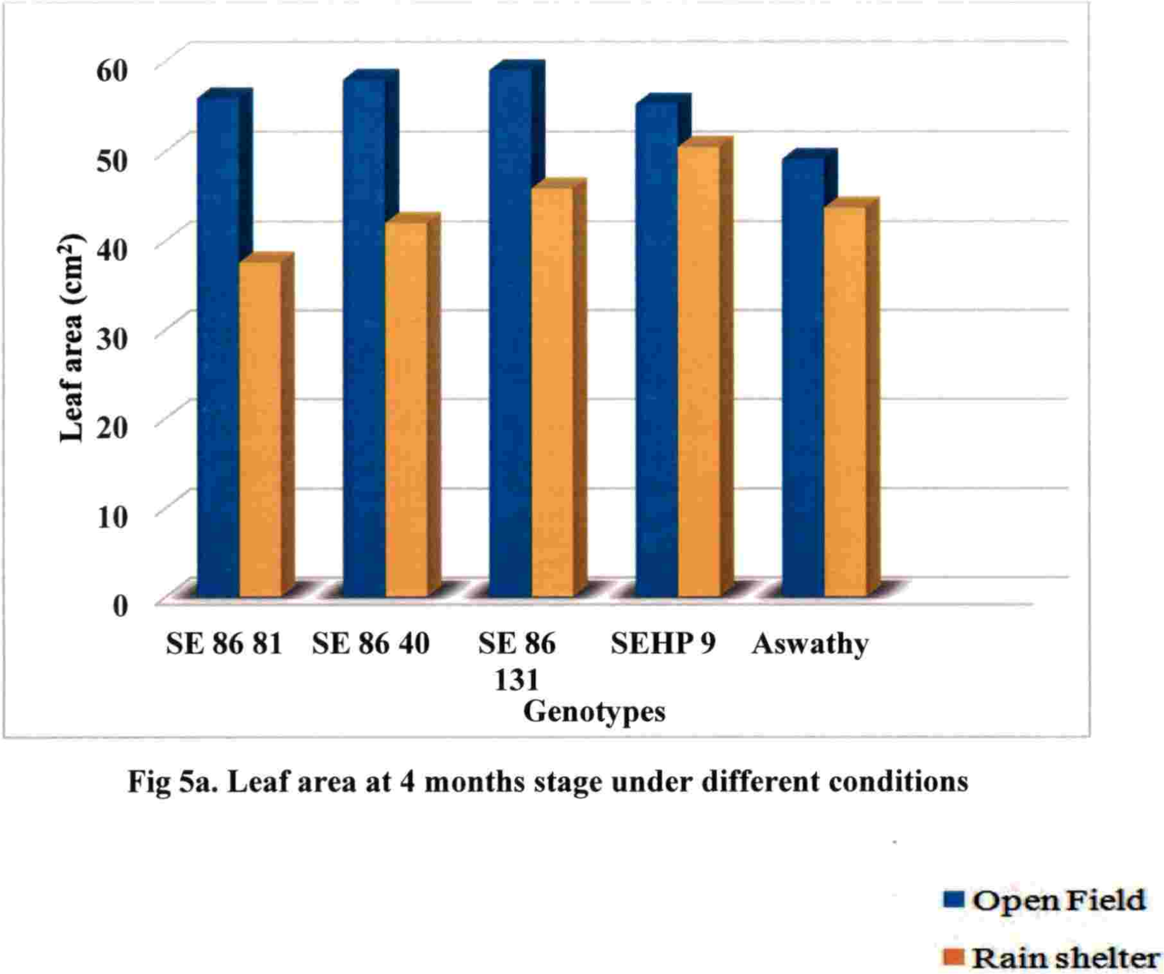

Fig 5a. Leaf area at 4 months stage under different conditions

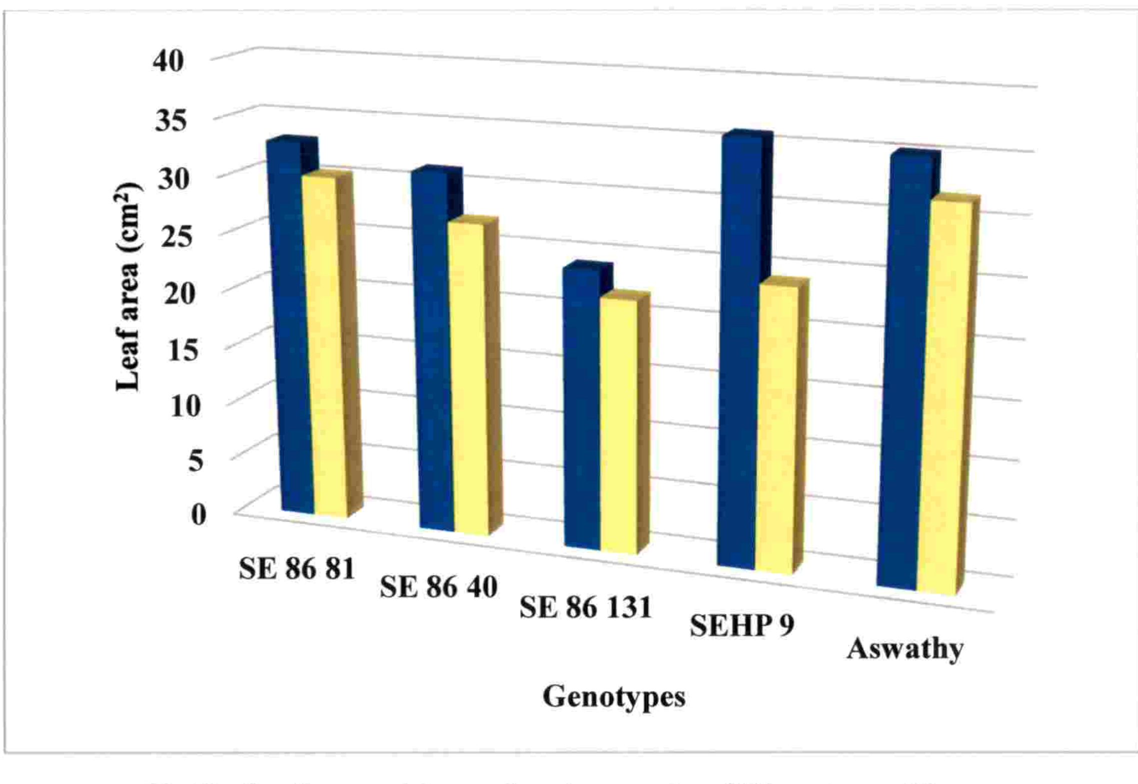

Fig 5b. Leaf area at 6 months stage under different conditions

indicate that in ginger in all growth stages leaf area is higher in open field than in rain shelter. Another observation is that leaf area increased with growth stages upto 5th month and later a decrease was noticed in all genotypes in both growing conditions. Significant differences in leaf area among the somaclones. may be due to the differences in leaf length and width which was influenced by genetic makeup of the varieties and also due to environmental condition. Low light intensity under rain shelter can be a reason for reduced leaf area due to restricted photosynthetic rate. Reduction in leaf length and width as the age advances was reported by Surendrababu *et al.* (2017). These results are in conformity with the findings of Singh *et al.* (2000), Kale (2001), Kuruber (2003), Anusuya (2004), Dhatt *et al.* (2008), Deshmukh *et al.* (2009), Jadhav *et al.* (2009), Muhammad *et al.* (2012), Iwo *et al.*(2011), Jyotsna *et al.*(2012), Bhuiyan *et al.* (2012), Rajalakshmi and Umajyothi (2014), Muhammad *et al.* (2012), Siddalingayya *et al.* (2014) and Virendra *et al.* (2015) in turmeric.

5.2.1.7 Yield

a. Fresh Yield

In almost all the somaclones, yield was higher than check variety Aswathy under both growing conditions (Figure 6). Yield per hectare was higher than 25 tonnes in three genotypes namely SEHP 9 (32.48 t), SE 8681 (28. 56 t) and SE 8640 (27.28 t). Even under rain shelter, the same three genotypes yielded more than 20 tonnes per hectare with highest value in SE 8640 (25. 24 t). Since there is no much difference in the yield of SE 8640 under open and rain shelter condition, it can be assumed that this somaclone is suitable for rain shelter cultivation also. Higher yield in somaclones are due to either more number of tillers, leaves and leaf area as evident from Table 17, 18 and 20.

These results are supported by the findings of Dev (2013) in an study conducted in ginger somaclone where fresh rhizome yield recorded among the somaclones ranged between 115.01 to 250.94 g on per plant basis, 3.68 to 8.03 kg per plot basis and 9.81 to 21.42 tonnes on a hectare basis. Surendrababu *et al.* (2017) stated that temperature and light intensity under rain shelter condition

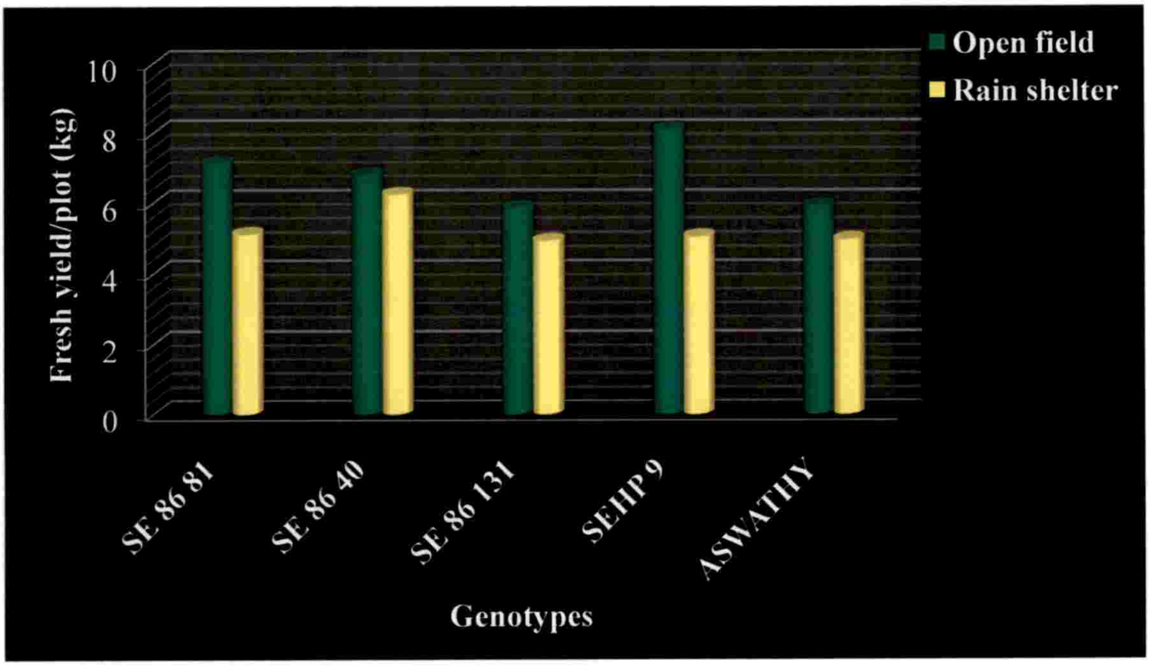

Fig 6. Fresh yield/ plot of different genotypes under different growing conditions

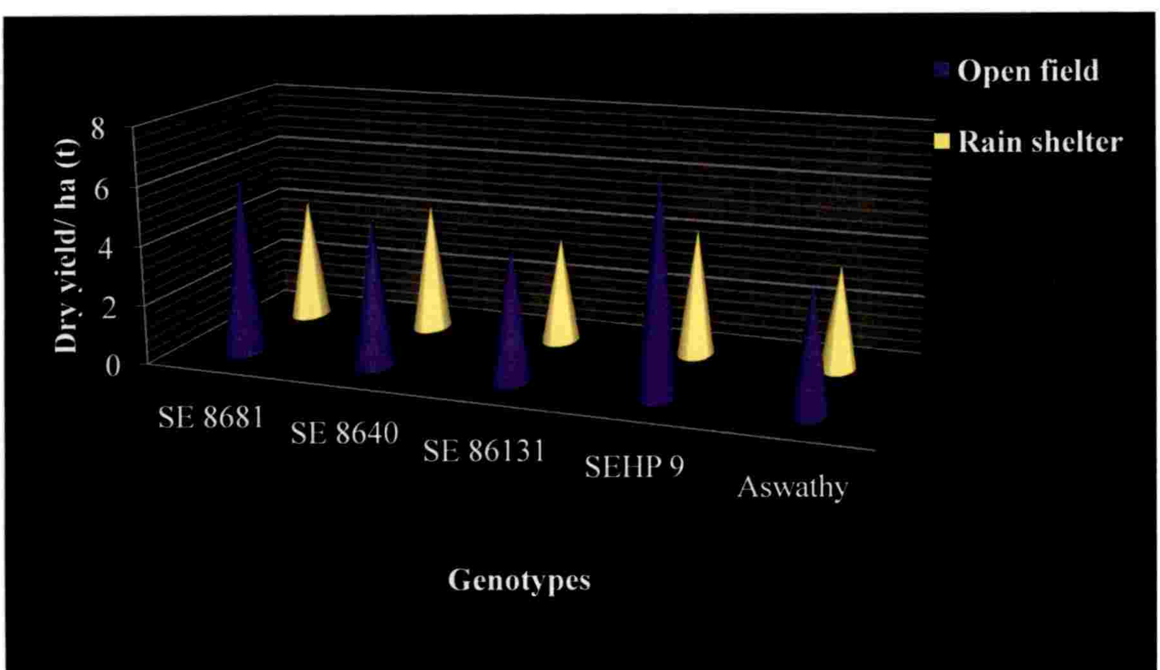

Fig 7. Dry yield/ha of different genotypes under different growing conditions

might have influenced the growth and yield of ginger. The rapid and more vegetative growth in open field condition stimulated increased sink in terms of rhizome size and thus increase in fresh rhizome yield per plant. The yield of the plant is a complex effect of various factors as genetic constitution of cultivars and its phenotypic expression under favorable environment condition. The similar results were also reported by Chongtham *et al.* (2013) in ginger and Virendra *et al.* (2015) in turmeric.

b. Driage and dry yield

Driage of ginger genotypes under open field condition ranged from 17.00 % (Aswathy) to 22.30 % (SEHP 9) and from17.23 % (Aswathy) to 21.02 % (SEHP 9) under rain shelter condition. Two genotypes namely SE 8681 and SEHP 9 recorded a driage of more than 20 % under both growing conditions. No significant differences was observed in the mean values for driage under two growing conditions (open and rain shelter) as revealed from the Table 22, whereas significant differences was noticed between genotypes for this character. SE 8681 (20.73 %) ans SEHP 9 (21.66%) recorded higher mean values (>20 %) for driage indicating their suitability for dry ginger purpose. Higher dry yield per hectare in SEHP 9 (7.24 t) and SE 8681 (6.06 t) in open field is due to higher driage and high rhizome yield. The dry recovery reported by Dev (2013) ranged from 15.89 to 21.21 per cent in different somaclones evaluated and similar results were reported by Goudar *et al.*, (2017)(Figure 7).

5.2.1.8 Physiological characters

At 2 MAP, chlorophyll index ranged from 40.90 (Aswathy) to 48.47 (SEHP 9) under open field condition (Table 23). In rain shelter, it varied from 39.08 (Aswathy) to 49.42 (SEHP 9). All the somaclones recorded chlorophyll index value above 45 except check variety Aswathy at two months stage. Chlorophyll index was higher at 4 months stages in all genotypes under both growing conditions and later chlorophyll index decreased. At 4 MAP, chlorophyll index under open field condition ranged from 42.29 (Aswathy) to 50.78 (SEHP

9), whereas in rain shelter SE 8640 registered the highest value of 52.00 which was on par with SE 8681 (50.70) and SEHP 9 (50.63). During 6 MAP, chlorophyll index under open field condition ranged from 33.99 in Aswathy to a highest value of 42.17 in SEHP 9. Under rain shelter condition values for this character ranged from 36.87 (Aswathy) to 43.78 (SE 8681) which was on par with 42.92 (SEHP 9). Higher values in SE 8681, SE 8640 and SEHP 9 may contribute to more photosynthesis resulting in higher yield as revealed from the yield data. Cholorophyll index was more in rain shelter at 4 MAP in SE 8681, SE 8640 and Aswathy, compared to open condition. This result is in conformity with the study of Sreekala *et al.* (2001) who reported that relatively low light intensity contributes to development of more chlorophyll in ginger plants.

Photosynthetic rate measured during 4 months stage under different growing conditions are given in Figure 8. Photosynthetic rate increased and reached maximum at 4 MAP and later decreased. Under open field, at 4 and 6 month stages, SE 8681, SE 8640 and SEHP 9 recorded higher values under both growing conditions than SE 86131 and Aswathy. Mean values of photosynthetic rate under different growing conditions indicate higher photosynthetic efficiency under open field condition (23.92 μmol $m^{-2}sec^{-1}$) than rain shelter (18.80 μmol $m^{-2}sec^{-1}$). Among the somaclones, SEHP 9 and SE 8640 recorded maximum values (23 μmol $m^{-2}sec^{-1}$) for photosynthetic rate irrespective of growing conditions. Higher photosynthetic rate in the somaclones may be the reason for obtaining higher yield as revealed from this study. In this study, from 4th month onward the relative humidity (%) of open field condition was very low compared to rain shelter (Appendix 1, Table c). Low relative humidity increase transpiration rate and stomatal conductance which can result in high photosynthetic rate.

The transpiration rate varied from 3.98 μmol $m^{-2}sec^{-1}$ (Aswathy) to 4.99 μmol $m^{-2}sec^{-1}$ (SE 86 81) under open field condition during 4 MAP (Figure 9) and in rain shelter, highest value was in SE 8640 (3.64 μmol $m^{-2}sec^{-1}$) and the lowest was for Aswathy (2.45 μmol $m^{-2}sec^{-1}$). During 6 MAP, the transpiration rate ranged from 0.82 μmol $m^{-2}sec^{-1}$ (Aswathy) to 3.62 μmol $m^{-2}sec^{-1}$ (SE 8681) under

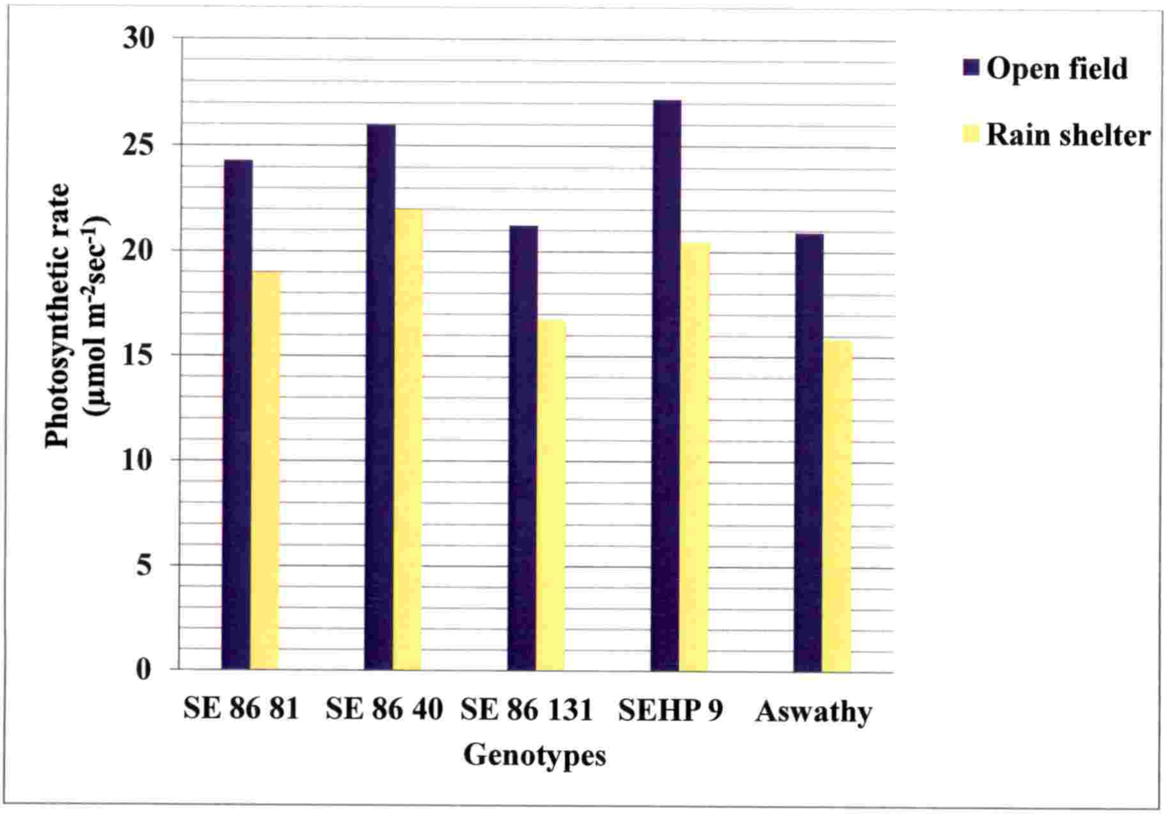

Fig 8. Photosynthetic rate at 4 months stage under different growing conditions

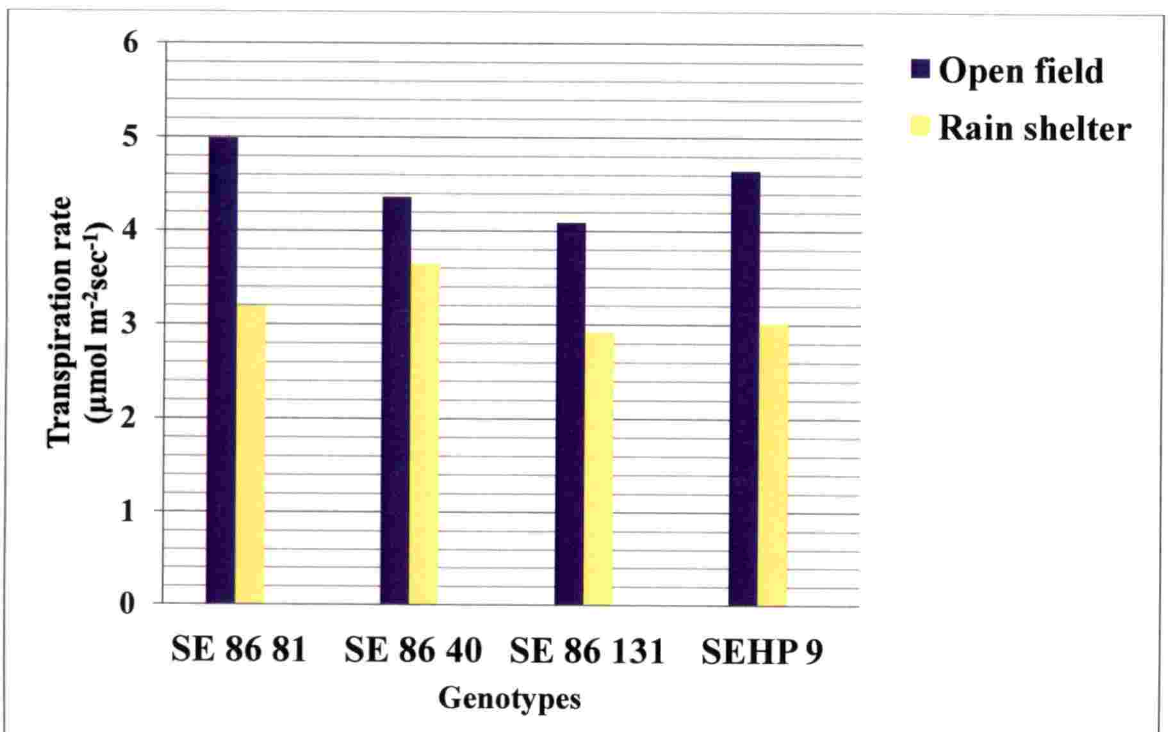

Fig 9. Transpiration rate at 4 months stage under different growing conditions

open field condition. In rain shelter, the transpiration rate ranged from 0.76 μmol $m^{-2}sec^{-1}$ (Aswathy) to 1.12 μmol $m^{-2}sec^{-1}$ (SE 8681). Transpiration rate was higher in SE 8681, SE 8640 and SEHP 9 compared to SE 86131 and Aswathy. Transpiration rate was higher in open field than in rain shelter.

Stomatal conductance during 4 MAP, varied from 0.08 m μmol $m^{-2}sec^{-1}$ (Aswathy) to 0.27 m μmol $m^{-2}sec^{-1}$ (SEHP 9).There was no significant difference among the somaclones on stomatal conductance under rain shelter condition. During 6 MAP, stomatal conductance under open field condition ranged from 0.02 m μmol $m^{-2}sec^{-1}$ (Aswathy) to 0.08 m μmol $m^{-2}sec^{-1}$ (SE 8681). Under rain shelter, SE 8681 recorded the highest stomatal conductance with a value of 0.05 m μmol $m^{-2}sec^{-1}$ and the lowest was in Aswathy (0.01 m μmol $m^{-2}sec^{-}1$). Among the growing conditions, higher stomatal conductance was observed in open field and among the genotypes, SE 8681, SE 8640 and SEHP 9 recorded higher mean values for this character.

In the present study, maximum values for physiological parameters such as photosynthetic rate, transpiration rate and stomatal conductance, were recorded at 4 months stage later declined. Mean values were significantly higher in open field condition compared to rain shelter. Observations indicated that photosynthetically active radiation of leaf surface as well as stomatal conductance were higher under open field condition leading to higher photosynthetic rate as well as transpiration rate in plants grown in open. According to Sreekala and Jayachandran (2001), stomatal conductance and stomatal frequency decreased with increasing shade levels, and were highest in plants grown under open conditions. Photosynthetic and transpiration rate decreased with decreased light intensity during growth stages. Ajithkumar *et al.* (2002) studied the effect of shade regimes on photosynthetic rate and stomatal characters using cv, Rio-de-Janeiro. They found that the highest photosynthetic rate was in the open conditions, followed by plants grown under 20 % and 40 % shade.

Low light intensity under rain shelter condition compared to open field is another factor affecting physiological parameters of crop under different growing conditions (Appendix 1, Table c). Low intensity of light cause stomatal closure, which restrict the entry of carbon dioxide, resulting in the decrease of photosynthetic rate. High light intensity on the other hand, increases the rate stomatal conductance which increased the rate of photosynthesis.

4.3 QUALITY PROFILING OF GINGER GENOTYPES UNDER DIFFERERNT GROWING CONDITIONS AND DIFFERERNT MATURITY STAGES.

Quality parameters such as volatile oil, oleoresin and crude fibre content of four ginger somaclones and check variety Aswathy was observed at two maturity stages grown under open field condition and in rain shelter. According to Purseglove *et al.* (1981), fibre and volatile oil contents and pungency levels are the most important criteria in assessing the suitability of ginger rhizomes for processing.

5.3.1. Volatile oil content

Volatile oil percentage ranged from 2.26 % to 4.45 % at 5 MAP under open field condition (Table 27). SE 8640 recorded the highest volatile oil content under both growing conditions (open field -4.45 % and rain shelter -4.67 %). Aswathy also recorded higher values under both growing conditions (3.50 % - open field and 3.63 % in rain shelter). Similarly at 7 month also volatile oil content was highest in SE 8640 under both growing conditions *viz.,* open field (3.30 %) and rain shelter (3.61 %) which was on par with the check variety Aswathy under both the growing conditions (2.37 % and 2.63 % respectively). Though the mean values for volatile oil content at different growing conditions did not differ significantly, higher recovery was observed in rain shelter cultivation than in open. At 7 month stage, volatile oil content was low when compared to 5 month stage. At both growing stages (5 and 7 months), SE 8640 and Aswathy recorded higher oil recovery as revealed from the mean values. Dev (2013) reported an oil recovery of 1.20 to 2. 32 % in ginger genotypes. According to Surendrababu (2017), volatile oil recovery under shade net condition ranged from 2.15 % (Narsipatnam Local) to 2.95 % (Himachal). Similar results were observed by Kanjilal *et al.* (1997) and Sanwal *et al.* (2012) in ginger.

5.3.2 Oleoresin content

Oleoresin percentage ranged from 4.12 % (SE 8640) to 6.01 % (SEHP 9) at 5 MAP under open field condition (Table 28). All genotypes except SE 8640 recorded an oleoresin content of more than 5 % under open field. Under rain shelter, SEHP 9 recorded the highest value of 6.72 % which was on par with SE 86131 (6.42 %), Aswathy (6.23 %) and SE 8681 (6.62 %). Here also all genotypes except SE 8640 recorded an oleoresin content of more than 6 % in rain shelter. At 7 MAP, the oleoresin percentage under open field condition ranged from 3.80 % to 4.51 %. Among the genotypes, SE 8681, SE 8640 and Aswathy recorded an oleoresin content of more than 4 %. In rain shelter, Aswathy registered the highest value of 5.49 % which was on par with SE 8681 (5.42 %) and the lowest was for SE 86131 (4.42 %). Though mean values for oleoresin content at 5 and 7 MAP did not vary significantly, higher values were observed under rain shelter condition (6.14 %) at 5 months stage. Later oleoresin content decreased and at 7 MAP higher values was observed under rain shelter condition (4.96 %) though not significantly differing on comparison with open field condition. Among genotypes, SEHP 9 (6.36 %) and SE 86131 (6.07 %) recorded higher mean oleoresin percentage at 5 months stage. In a study conducted by Dev (2013), oleoresin content ranged between 4.34 to 8.59 per cent in the ginger somaclones. Variations in oleoresin content in rain shelter and open field might be due to difference in soil temperature and micro climatic conditions. Surendrababu *et al.* (2017) conducted similar study under shade net condition and reported that, oleoresin content ranged from 6.20 to10.10 %. Similar results were reported by Kale (2001), Iwo *et al.* (2011) and Nileena *et al.* (2014) in ginger.

5.3.3 Crude Fibre

Crude fibre content increased from 5 months stage to 7 months stage in all genotypes (Table 29). Crude fibre content varied from 1.70 % (SE 131) to 1.98 %

(SEHP 9 and Aswathy) at five month maturity under open field condition. In rain shelter, SE 8681 registered the lowest value of 1.46 % and higher crude fibre content (> 1.80 %) was registered for SEHP 9 (1.83 %) and Aswathy (1.87 %). At 7 months maturity, SE 8640 recorded the lowest crude fibre content (2.24 %) under open field condition and SEHP 9 recorded the highest (3.43 %). In rain shelter, SE 8640 recorded the lowest value of 2.26 % and the highest was for Aswathy (3.02 %) and SEHP 9 (3.12 %). Mean values for crude fibre content under different growing conditions resulted in higher values under open field (1.87 % at 5 MAP and 2.95 % at 7 MAP). At 7 MAP, fibre content was higher than at 5 MAP in all genotypes. Among genotypes, SE 8681, SE 8640 and SE 86131 recorded lower fibre content than SEHP 9 and Aswathy. The somaclones showed lower crude fibre content and it is considered as a desirable quality attribute for fresh ginger and value added products. Dev (2013) evaluated ginger somaclones for crude fibre and observed that the values ranged from 1.25 to 4.05 per cent among the somaclones. Crude fibre content ranged between 2.00 to 3.86 per cent among somaclones evaluated by Kankanawadi (2015). Though increase in fiber content was noticed up to the last stage of harvesting, maximum rise in the fibre content was observed between 150 to 180 days of planting (Sanal *et al.* 2010). Similar trend for crude fibre in ginger was reported by Ratnambal *et al.* (1987).

In the present study, volatile oil and oleoresin content was observed highest at 5 MAP and later it declined whereas crude fibre content of ginger genotypes increased with maturity. Generally, volatile oil, oleoresin and crude fibre content was high in rain shelter grown ginger plants. The relative abundance of these three components is governed by stage of maturity at harvest as reported by Natarajan *et al.* (1972). Winterton and Richardson (1965) claimed that oleoresin and oil contents rose sharply up to 5, to 6 months beyond which there was a decline and fibre development was extemely rapid between 6 and 7 months of growth. According to Aiyadurai (1986), crude fibre content increased beyond 260 DAP. Although there is fibre in the -rhizome from the time it begins to develop, the amount is non significant in the initial stages. As the physiological age of rhizome increases, the diameter and strength of fibre also increases. Fibrous ginger is unacceptable for processed confectionary because of its reduced palatability. Harvesting of confectionary grade ginger thus begins when 40 to 50 per cent by weight of the rhizome is free of commercial fibre, and continues down to 35 per cent level (Whiley, 1980). Increase in crude fibre and decrease in fat and protein content of rhizome were noticed after 6 months (Jogi *et al.* 1972). Oleoresin and oil content for different cultivars reached its maximum 265 days after planting (Nybe *et al.* 1980). Ratnambal (1987) observed that dry recovery; starch and crude fibre were positively correlated with maturity whereas essential oil, oleoresin and protein were negatively correlated with maturity.

5.4 SCREENING GINGER SOMACLONES FOR PRODUCT DEVELOPMENT

Yield and quality are the important attributes contributing to the product development in ginger. Physical characteristics like moisture and colour, biochemical characters like pH, titratable acidity along with peeling are important prerequisites in the product development. The somaclones namely SE 86 26, SE 86 83, C 86 26, CHP 118, C 78 284, SE 86 102, SE 86 42, C 86 32, CHP 99 and CHP 282 and a released variety Aswathy were evaluated for the quality and three products such as candy, flakes and powder were prepared. The prepared products were packed in HDPE cover and were stored for six months under room temperature. The sensory evaluation for colour, flavour, texture and overall acceptability of these products were done by a panel of 15 trained judges on a nine point hedonic scale after preparation and during storage.

5.4.1. Easiness in peeling

Peeling of ginger is an important step and a prerequisite for preparation of various value added products. After washing the ginger rhizomes were subjected to peeling operation. Conventionally, peeling of ginger is done by scrapping with sharpened bamboo stick. Since ginger rhizomes are irregular in shape and not in a

Candy

Powder

Flakes

Plate 12. Ginger products prepared from genotypes

spherical geometry, peeling process is a very tedious, time consuming and labour intensive operation. Inspite of machines developed for peeling, manual peeling is preferred in ginger (Agarwal *et al*, 1986 and Ali *et al*, 1991). Easiness in peeling was assessed for ten somaclones and the variety Aswathy (Table 1). Based on time required for hand peeling at five and seven month maturity stages, they were categorized as easy, moderate and difficult to peel types. At five months maturity, somaclones exhibited difference in easiness for peeling. It was observed that four somaclones SE 8626, SE 8683, SE 86102 and CHP 282 were very easy to peel, six somaclones such as C 8626, CHP 118, C 78 284, SE 86 42, C 86 32 and CHP 99 were moderately easy to peel and Aswathy was difficult to peel when compared to other somaclones.

At seven months maturity, SE 8683 was found to be much easy to peel compared to other somaclones and Aswathy. Majority of the somaclones at this stage such as SE 86 26, SE 86 102, C 86 26, CHP 118, C 78 284, SE 86 42 and C 86 32 were found to be moderately easy to peel. The somaclones CHP 99, CHP 282 and the check variety Aswathy were found to be difficult types to peel at seven month stage. It was found that as the maturity increased peeling of ginger rhizomes were found difficult compared to the vegetable maturity stage. This may be due to the loss of moisture in the rhizomes during maturity. However somaclone SE 8683 was easy to peel at both maturity stages and Aswathy was difficult to peel at both maturity stages and hence the somaclone can be used for product development.

5.4.2. Recovery of ginger products

The recovery of ginger candy of ten somaclones ranged from 53.41 % to 78.41 %. The somaclone SE 8642 recorded the highest recovery percentage of 78.41, followed by C 8626 (78.24 %). Somaclone SE 8626 registered lowest recovery (53.41 %). Among the somaclones SE 8683, SE 86102, CHP 118, CHP 282 and Aswathy recorded recovery more than 70 percantage. The recovery of ginger flakes ranged from 6.40 % to 18.21 %.The somaclone SE 8626 recorded significantly highest value of recovery (18.21 %) followed by C 8626 (16.80 %) and the lowest recovery was registered in SE 86102 (6.40 %). SE 8626, C 8626, CHP 118 and SE 8642 showed recovery more than 10 percentage compared to others. The recovery of ginger powder ranged from 15.20 % to 28.80 % with SE 8642 recording significantly highest value of recovery (18.21 %) to other somaclones and check variety followed by SE 86102 (22.41 %).The lowest recovery was registered in C 78284 (15.20 %). Somaclones SE 86102, CHP 282 and Aswathy showed recovery more than 20 percentage compared to others.

5.4.3. STABILITY OF QUALITY PARAMETERS OF GINGER CANDY DURING STORAGE

5.4.3.1 Physical characteristics

The initial moisture content of ginger candy from the somaclones and check variety ranged from 3.90 to 7.41 % (Figure 10). There was an increase in moisture content during storage. At final stage of storage moisture content of ginger candy ranged from 8.22 to 11.14 %. Somaclones C 78284, SE 8642, C 8632, CHP 99 and CHP 282 recorded moisture content below seven percentage. Increase in moisture content in dried apricot slices packed in polyethylene packets was reported by Sharma *et al.* (2000).They opined that moisture increase might be due to the permeability of polyethylene packs to air and vapours. Similar result was reported by Shobha *et al.* (2018) supporting that increase in moisture content was due to permeability of air as well as entrapment of air during sealing and handling during packing.

Color is one determinant of quality in food products in addition to the nutritional value. The visual assessment of color usually comes first, as it can attract consumers and can also be used as an indicator of freshness of the product. Initially when ginger candy from different somaclones and variety was observed, SE 8626 and C 78284 exhibited Light Orangish Yellow (19 A) colour, SE 8683, C 8626, CHP 118 and CHP 118 showed Light Yellow (18 A) colour, SE 86102 exhibited Moderate Orangish Yellow (164 B) colour, CHP 282 exhibited

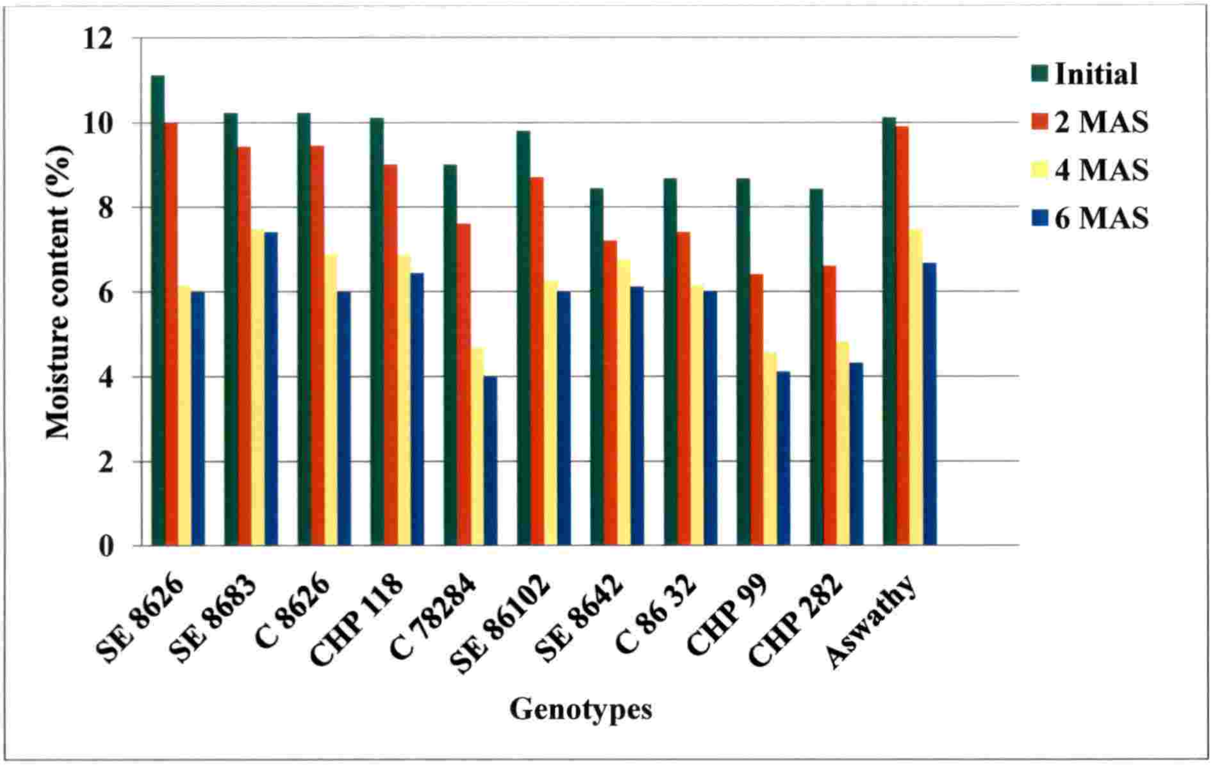

Fig 10. Effect of storage on moisture content (%) of ginger candy

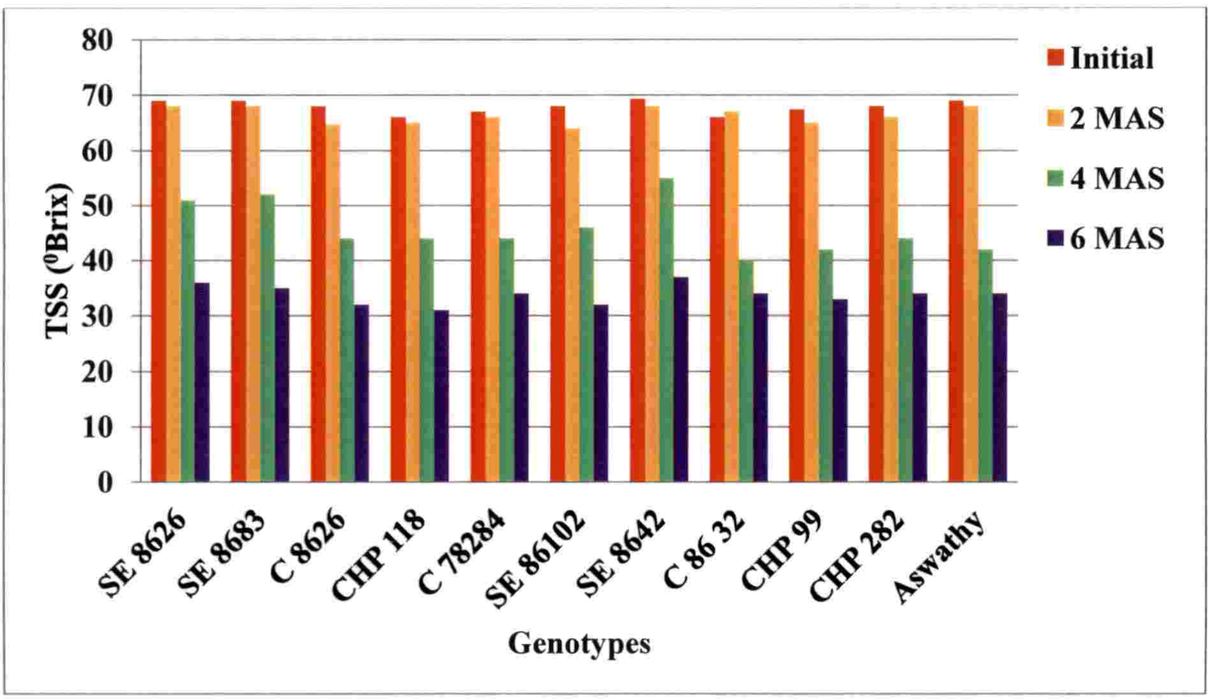

Fig 11. Effect of storage on TSS of ginger candy

(MAS – Months After Storage)

Moderate Yellow (162 A) and SE 8642, C 8632 and Aswathy showed Pale Yellow (18 A) colour. Compared to initial colour, there was no notable change during storage, in the candies from all the somaclones except for the variety Aswathy which showed slight colour change from Pale Yellow (18 D) to Pale Yellow (20 D), at 4 MAS. This could be mainly due to non-enzymatic reactions such as organic acid with sugar or oxidation of phenols which leads to colour change of the product. At 6 months after storage variety Aswathy showed Pale Yellow (20 D), while there was no significant colour change for other somaclones even at final stage of storage. This indicates the somaclonal influence on product stability.

5.4..3.2 Biochemical parameters

TSS content of ginger candy ranged from 66.10 to 69.50 ^{0}Brix, with somaclones SE 8626, SE 8642 and C 8626 recording highest values (69.50, 69.31 and 69.20 ^{0}Brix respectively) (Figure 11). Minimum TSS content (66.10 ^{0}Brix) was registered in CHP 99. This might be due to the effect of blanching up to a certain limit, which caused an increase in TSS through softening of the tissues and permitting faster penetration of sugar through osmosis. Longer blanching time will increase the permeability of cell wall and solid gain will increase with immersion time, blanching time and syrup temperature. Similar results were reported by Alam *et al.* (2010) for aonla slices and Nath *et al.* (2013) for ginger candy. In this study, TSS content of ginger candy showed a decreasing trend during storage. At the final stage of storage, the TSS content of ginger candy ranged from 31.40 to 37.50 ^{0}Brix and it was the candy from SE 8642 showed highest value of 37.50 ^{0}Brix followed by SE 8683 (36.20 ^{0}Brix). Minimum TSS content was observed SE 86102 (32.06 ^{0}Brix). The overall decrease in TSS may be attributed to increase in moisture of the product in storage.

The pH value of a food is a direct function of the free hydrogen ions present in that food. Acids present in food release these hydrogen ions, which give the food their distinct sour flavor. Thus, pH may be defined as a measure of free acidity. According to Akhtar *et al.* (2013) the pH value of ginger rhizome varied between 5.23 to 6.72. pH value of ginger rhizome was 6.30 as reported by Shirshir *et al.* (2012).According to Rahman *et al.* (2013) pH value of ginger rhizome was 6.15. According to U.S. Food and Drug Administration, (2008) approximate pH value of the fresh ginger varied from 5.60 to 5.90, whereas the pH content of freshly prepared ginger candy from different genotypes was observed from 3.50 to 4.10. During storage, pH content of ginger candy from different genotypes showed a decreasing trend and final stage of storage, pH value of the product ranged from 3.15 to 3.52 (Figure 12).

Initial titratable acidity observed for ginger candy from different genotypes ranged between 0.10 to 0.19 % (Figure 13). The minimum value (0.10 %) for titratable acidity was observed in somaclones SE 8626, C 8626 and SE 8642. Titratable acidity of ginger candy from different somaclones showed an increasing trend during storage. At final stage of storage, titratable acidity of ginger candy ranged from 0.16 to 0.26 % with minimum in SE 8642 (0.16 %). Sethi (1980) reported a gradual increase in the acidity values of aonla preserve during storage. Similar trend was observed by Rao and Roy (1980) in dehydrated mango pulp and dates. This might be attributed by the formation of acids due to interconversion of sugars and other chemical reactions (Clydesdale, 1972) which were accelerated at high ambient temperature (Rao and Roy, 1980).

5.4.3.3 Microbial population in ginger candy

Menon (2000) reported low microbial counts in dehydrated fruits and vegetables, dried to moisture content less than 3 per cent after blanching and drying. In ginger candy, no bacterial mould and yeast growth was detected in any of the somaclones immediately after preparation and also at 2 and 4 MAS (Table 7). However it was found in few somaclones after 6 months of storage such as CHP 118 (3.20 X 10^{-5}), C 78284(3.03 X 10^{-5}) and CHP 282 (3.00 X 10^{-5}), mould in CHP 282 (1.00 X 10^{-2}) yeast population was observed in CHP 99 (1.00 X 10^{-3}) among the somaclones and check variety Aswathy. Microorganisms in food products are influenced by inherent characteristics in the food such as moisture content, nutrient composition and pH (Frazier and Westhoff, 1998) (Plate 12.)

5.4.3.4 Sensory evaluation

The prepared ginger candy was subjected to sensory evaluation and the best somaclones for ginger candy preparation were identified based on the sensory scores (Appendix II). The study showed that the color, flavor, texture and overall acceptability among the candies were different. Total score for ginger candy from different somaclones ranged from 65.39 to 44.87. Candy from somaclone SE 8642 was identified as the best sample as its score for appearance, colour, flavor, texture, odour, taste, after tatse, overall acceptability and total score was the highest (65.39) compared to other soamclones, followed by C 8626 (65.02) and SE 8683 (60.98). Candy from C 78284 was considered the least preferred since its score for appearance, colour, flavor, texture, odour, taste, after tatse, and overall acceptability contributing to lowest total score (44.87). Other acceptable genotypes for candy are SE 8626, SE 86102, CHP 282 and Aswathy (Table 8).

Sensory score of ginger candy from different genotypes showed a declining trend during storage. After six months of storage, C 8626 obtained maximum total score (58.53) followed by SE 8642 (58.28).Minimum total score was recorded by C 8632 (41.29). Somaclones SE 8626 and SE 8683 are others under acceptable limits based on the score recording more than 50 (Figure 20).

5.4.4. STABILITY OF QUALITY PARAMETERS OF GINGER FLAKES DURING STORAGE

5.4.4.1 Physical characteristics

Initial moisture content of ginger flakes ranged from 6.00 to 7.40 %, with somaclone C 8632 recording highest value (7.94 %) followed by SE 86102 (7.40 %), SE 8626 (7.37 %), CHP 118 (7.10 %) and Aswathy (7.05 %) (Figure 14). Minimum moisture content (6.00 %) was observed in SE 8683, C 8626 and SE 8642. Moisture content of ginger flakes from all somaclones and check variety showed an increasing trend during storage. At 6 MAS, moisture content of ginger flakes ranged from 6.79 to 9.10 %. Minimum moisture content was observed in

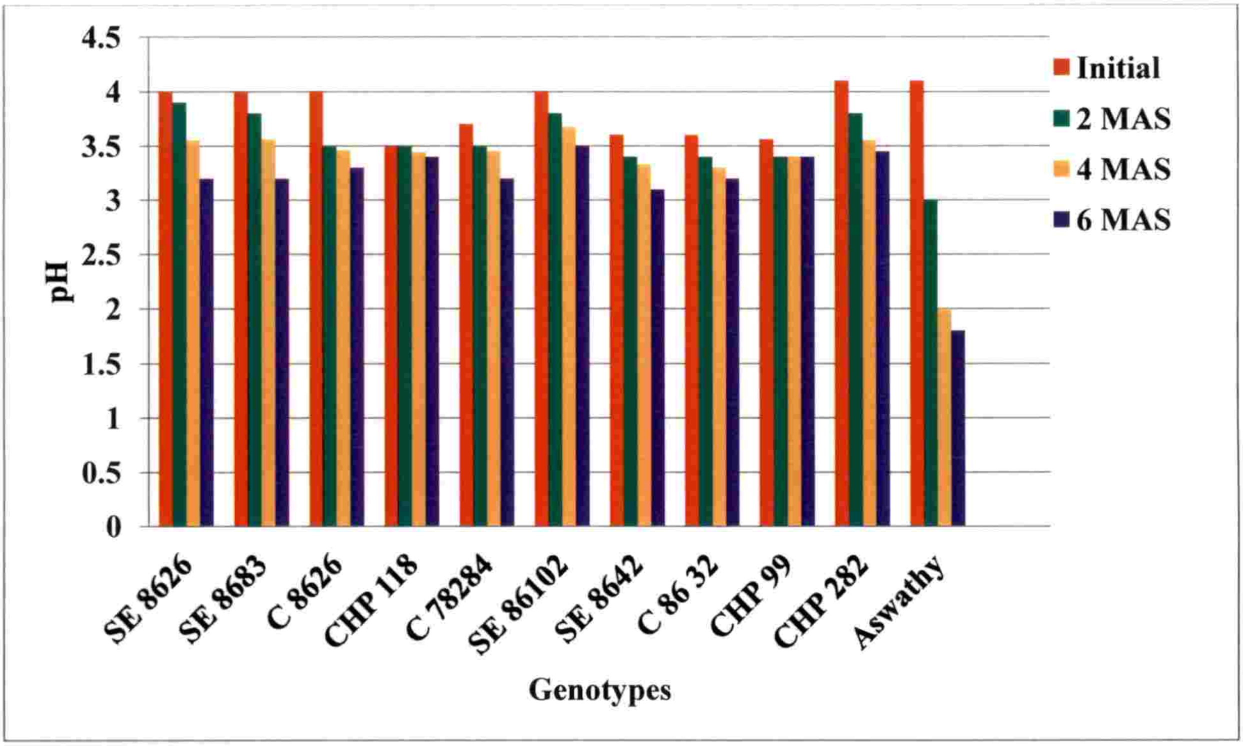

Fig 12. Effect of storage on pH of ginger candy

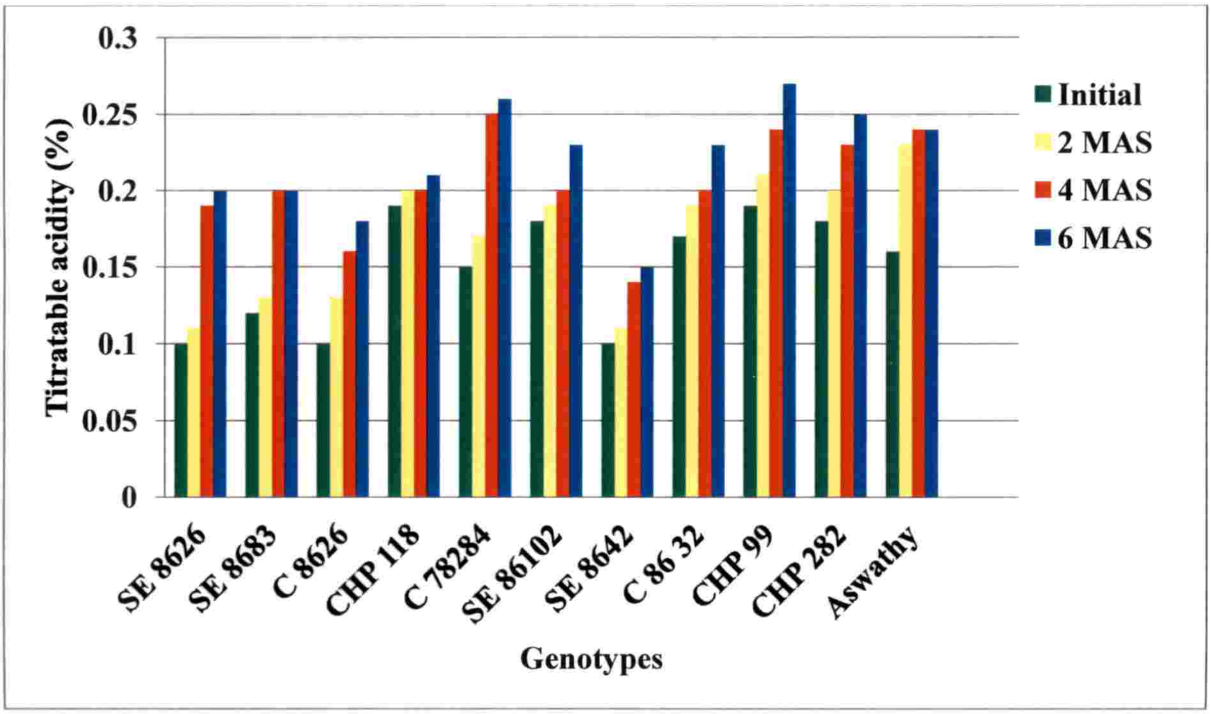

Fig 13. Effect of storage on titratable acidity(%) of ginger candy

(MAS – Months After Storage)

somaclones SE 8683 (6.79 %). The highest was in C 8632 (9.10 %) followed by SE 86102 (8.10 %), SE 86826 (8.00 %) and CHP 118 (8.00 %).

Colour is an important sensory attribute because it is usually the first property the consumer observes. Loss of colour and increased browning during processing and storage of processed foods are influenced by many factors like pH, acidity, storage temperature and duration (Garcia *et al.*, 1990). Because of these factors studies on degradation of colour during storage have practical importance to the processing industry. Initial colour of ginger flakes from different somaclones and Aswathy was observed, SE 8626 exhibited Pale Yellow (158C) colour, SE 8683, C 8626 and CHP 118 exhibited Yellowish White (158 C) colour, C 78284 and Aswathy showed Pale Yellow (20 D) colour, SE 8642 with Yellowish White (158 D), SE 86102 with Pale Yellow (158 B) and C 8632 and CHP 282 with Pale Yellow (158 D) colour.

There was no notable colour change in ginger candy from different somaclones during 2 and 4 MAS except C 78284 which showed a colour change from Pale Yellow (20 D) to Pale Yellow (20 C) at 4 month stage. During final stage also there was no notable colour change in ginger flakes. However C 78284 showed Pale Yellow (20 C) colour at this stage.

5.4.4.2 Biochemical parameters

pH signifies the acidic or basic nature of the ginger flakes and determines the survival and growth of microorganisms during processing and storage (Figure 13).Initial pH content of ginger flakes from different somaclones was observed from 3.90 to 5.58, with the maximum in somaclone SE 8626 with a value of 5.58 which was followed by SE 8642 (4.55). The minimum value for pH was observed in somaclone CHP 99 and Aswathy (Table 15). pH content of ginger flakes from different somaclones showed an increasing trend during storage. At 6 MAS, pH content of ginger flakes ranged from 4.80 to 6.21. The maximum pH was registered in somaclone SE 8626 with a value of 6.21 and was followed by C 78284 (5.80) and CHP 118 (5.95).The minimum value for pH was observed in Aswathy (4.80).

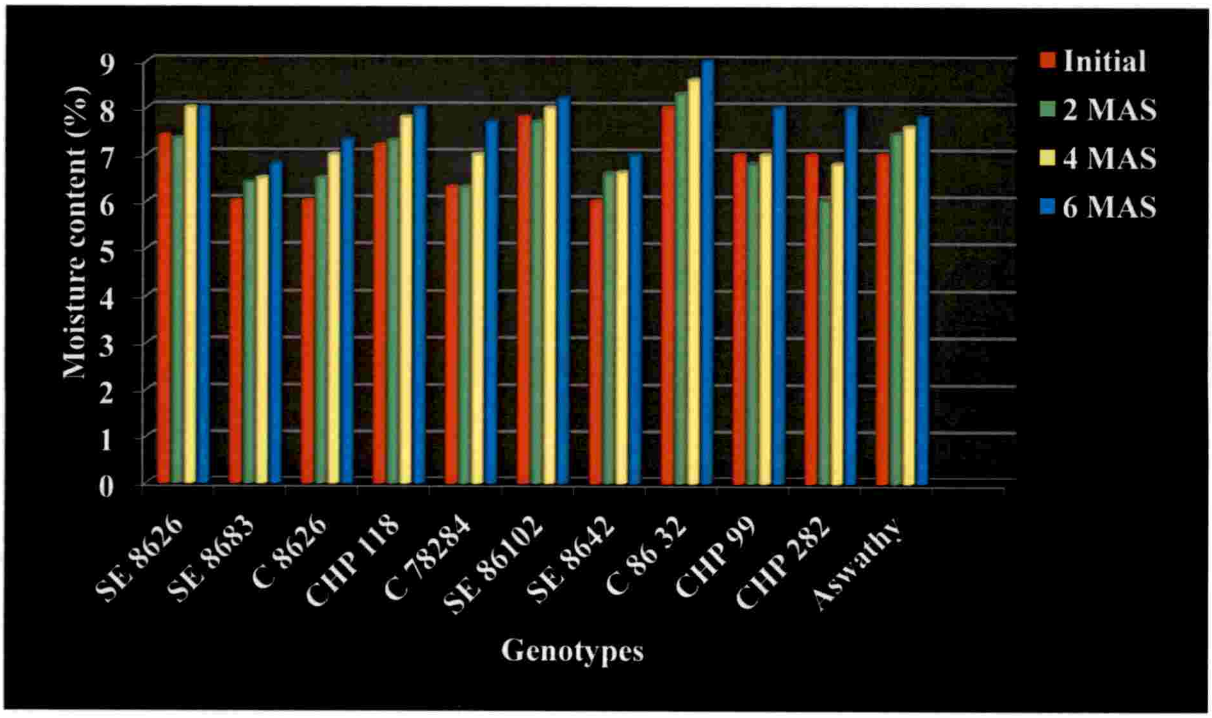

Fig 14. Effect of storage on moisture content (%) of ginger flakes

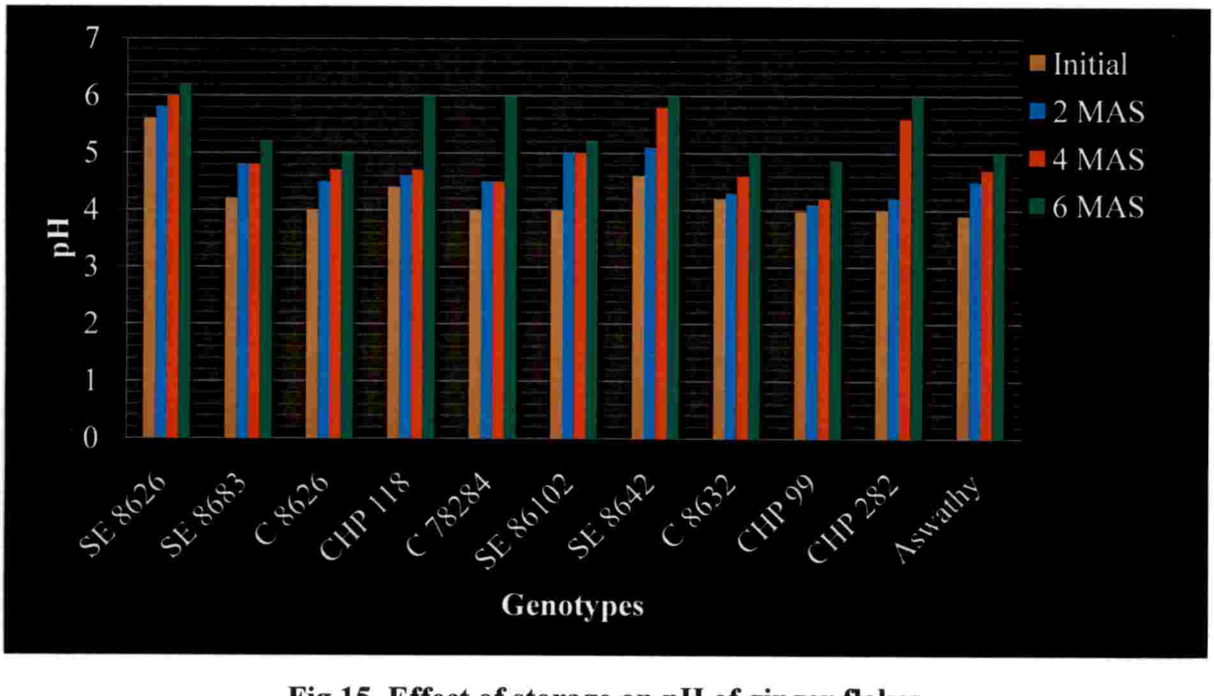

Fig 15. Effect of storage on pH of ginger flakes

(MAS – Months After Storage)

Initial titratable acidity observed for ginger flakes from different genotypes including Aswathy ranged between 1.10 to 1.58 %, with the maximum in somaclones SE 8610 and SE 8642 with a value of 1.58 followed by Aswathy (1.41 %) (Figure 16). The minimum value (1.10 %) for titratable acidity was observed C 8632 (Table 16). Titratable acidity of ginger flakes showed a decreasing trend during storage. At 6 MAS, titratable acidity of ginger flakes ranged from 0.31 to 0.61%. The maximum titratable acidity (0.61 %) was registered in somaclone SE 86102 and was on par with SE 8642 (0.60 %) followed by C 8626 (0.49 %), CHP 99 and Aswathy with a value of 0.50 % titratable acidity. The minimum value was observed in C 8632 (0.31 %). The decrease in titratable acidity during storage might be due to utilization of acid for conversion of non reducing sugars to reducing sugars and for non enzymatic reactions (Sharma *et al.* 2004). Decrease in titratable acidity during storage has been reported by Sagar and Khurdiya (1999) in dehydrated mango slices, Sharma *et al.* (2000) in osmo-air dried apricot packed in glass jar and aluminium laminated pouches, Sharma *et al.* (2006) for aluminium laminated pouches of packed dehydrated apple rings, Raj *et al.* (2006) in dehydrated onion rings, Dhiman (2015) in ginger flakes and Ahmed *et al.* (2014) in osmo dried peach slices.

5.4.4.3 Microbial population in ginger flakes

The absence of any microbial growth during the entire period at ambient temperature exhibited good storage stability of the product. The maximum limit of microbial colonies in dried fruits and vegetable products according to FSSAI (2006) is 40,000/g. In ginger flakes, no bacterial growth was detected in any of the somaclones immediately after preparation and also at 2 and 4 MAS. However it was found in somaclones CHP 282 (4.20 X 10^{-5}) and CHP 99 (5.11 X 10^{-5}) after 6 months of storage (Table 17).No mould and yeast growth was detected in ginger flakes of different somaclones from initial to final period of storage study.

5.4.4.4 Sensory evaluation

Total score for ginger flakes from different somaclones at initial stage ranged from 43.90 to 64.14 (Appendix II). Flakes from somaclone SE 8683 was identified as the best sample as its score for appearance, colour, flavor, texture, odour, taste, after tatse, overall acceptability and total score was the highest (64.14) compared to other soamclones, followed by SE 8642 (63.26) and C 8626 (61.80). Flakes from CHP 118 was considered the least preferred since its score for appearance, colour, flavor, texture, odour, taste, after tatse, and overall acceptability contributing to total score, was the lowest (43.90). Other acceptable somaclones are SE 8626, CHP 282 and Aswathy (Table 21).

Sensory score of ginger falkes from different somaclones showed a declining trend during storage. After six months of storage, SE 8683 recorded the highest total score of 58.66 followed by SE 8642 (58.40), C 8626 (58.12) and SE 8626 (51.86) (Figure 20). Minimum total score was recorded by CHP 118 (40.16) (Table 21).

Osmotic dehydration in processing of dehydrated foods has some advantages such as minimizing heat damage to the colour and flavour, inhibiting enzymatic browning and reducing energy costs (Alakali *et al.*, 2004). Thus it has received more consumer demand in minimally processed products like ginger flakes.

5.4.5. STABILITY OF QUALITY PARAMETERS OF GINGER POWDER DURING STORAGE

5.4.5.1 Physical characteristics

Initial moisture content of ginger powder ranged from 6.00 to 9.05 %, with somaclone CHP 282 recording highest value (9.05 %) followed by SE 86102 (7.74 %). Minimum moisture content was observed in SE 8626 (5.90 %), C 8626 and SE 8642 with a value of (6.00%) (Figure 19).

Moisture content of ginger powder from all somaclones and check variety showed an increasing trend during storage. At 6 MAS, moisture content of ginger

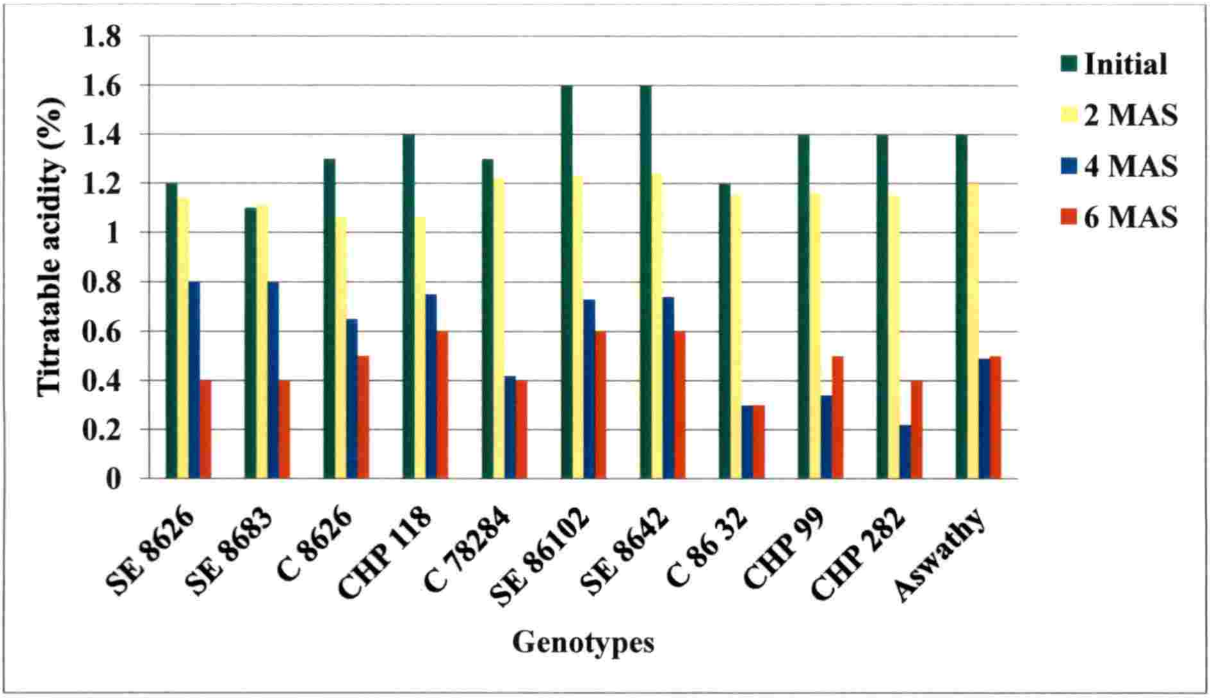

Fig 16. Effect of storage on titratable acidity (%) of ginger flakes

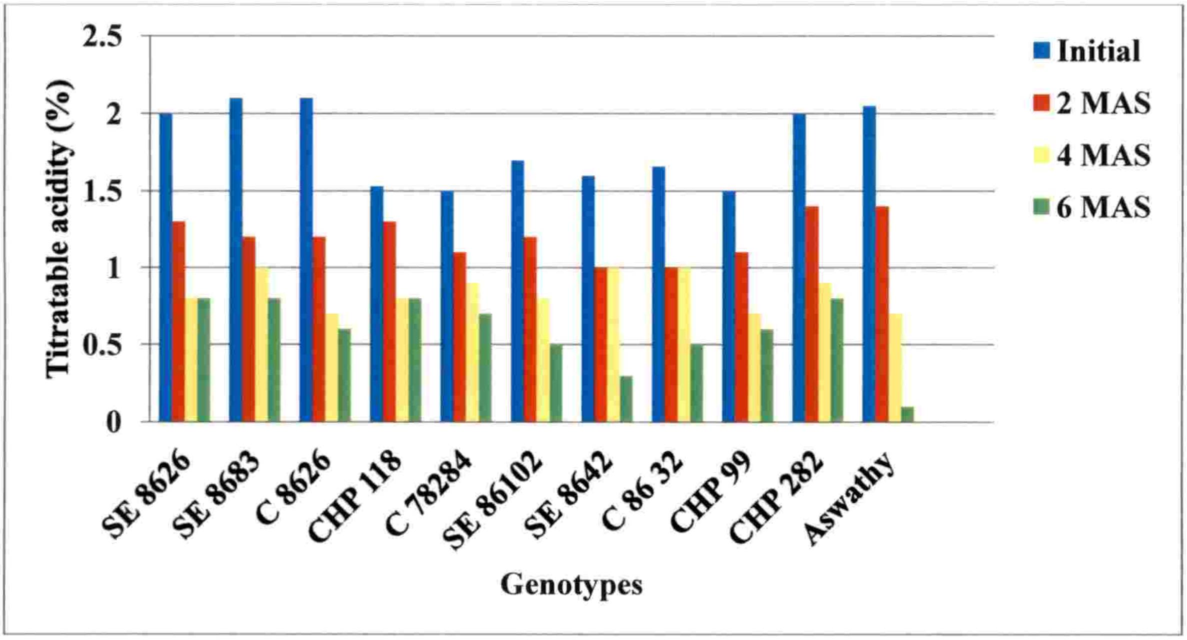

Fig 17. Effect of storage on titratable acidity (%) of ginger powder

(MAS – Months After Storage)

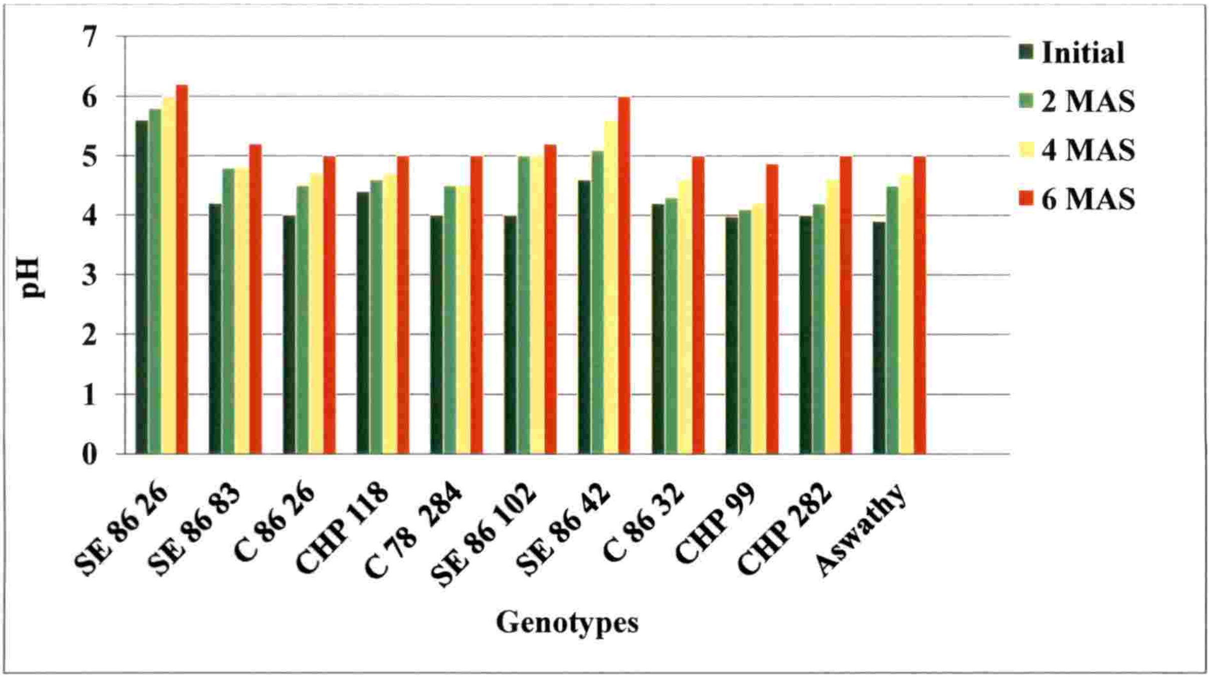

Fig 18. Effect of storage on pH of ginger powder

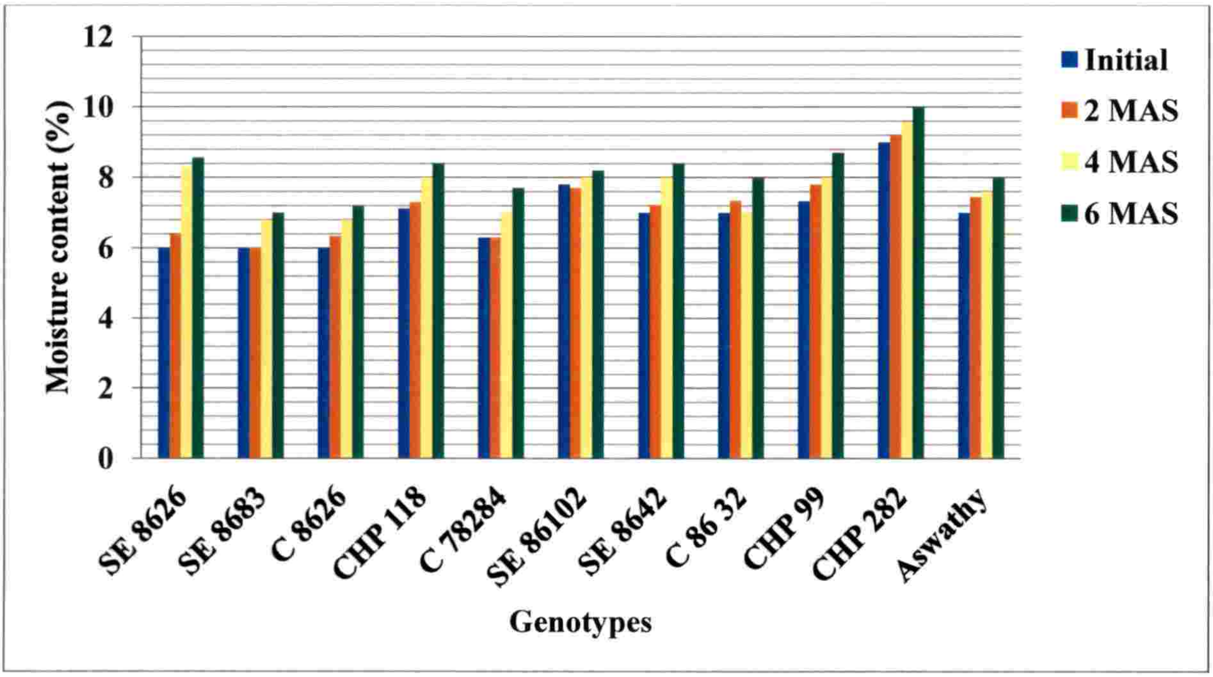

Fig 19. Effect of storage on moisture content (%) of ginger powder

(MAS – Months After Storage)

powder ranged from 7.00 10.00 %. Highest moisture content was observed in somaclones CHP 282 (10.00 %) followed by CHP 99 (8.69 %). Minimum moisture content was in SE 8683 (7.00%).

In general, higher drying air temperature affects colour of dried product due to a non-enzymatic browning reaction (Phoungchandang, 2008) .Colour of ginger powder was assessed by using Royal Horticulture Society Colour Chart (Edition V) (Table 23). Initially ginger powder from different somaclones and check variety observed, SE 8626 and CHP 118 exhibited Pale Yellow (158 A), SE 8683 exhibited Pale Yellow (12 D), C 8626 showed Yellowish White (158 C), C 78284 and CHP 282 showed Pale Yellow (158 B), SE 8642 with Yellowish White (158 D), CHP 99 with Pale Yellow (11 D) and Aswathy with Pale Yellow (8 D). There was no notable colour change in ginger powder from different somaclones during storage except C8632, SE 8626 and Aswathy. Whereas all others remained in the same colour.

5.4.5.2 Biochemical parameters

Initial pH content of ginger powder from different somaclones was observed from 3.94 to 5.53, with the maximum in somaclone SE 8626 with a value of 5.53 which was followed by SE 8642 (4.60) (Figure 18). The minimum value for pH was observed in somaclone CHP 99 (3.94) and Aswathy (3.95) (Table 24). pH content of ginger powder from different somaclones including check showed an increase. At 6 MAS, pH content of ginger powder ranged from 4.84 to 6.20. The maximum pH was registered in somaclone SE 8626 with a value of 6.20 and was followed by SE 8642 (6.00). The minimum value for pH was observed in the check CHP 99 (4.84). The increased pH was due to the decrease in acidity of the powder.

Initial titratable acidity observed for ginger powder from different somaclones including Aswathy ranged between 1.48 to 2.06 %, with the maximum in somaclone C 8626 (2.06 %) which was on par with CHP 282 (2.05 %) and Aswathy (2.04 %) (Figure 17). The minimum value for titratable acidity was observed CHP 99 (1.50 %) and CHP 118 (1.53 %) (Table 25). Titratable

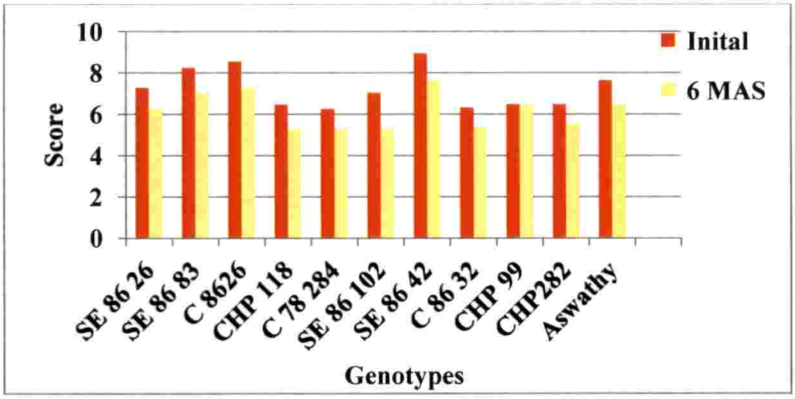

Fig 20. Sensory score of ginger candy

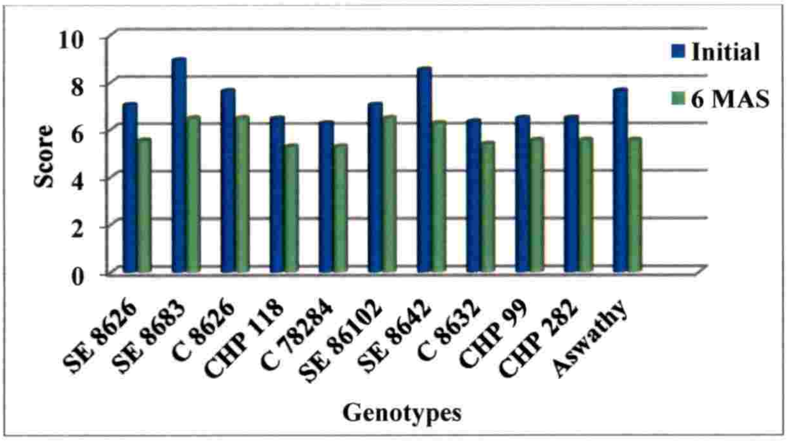

Fig 21. Sensory score of ginger flakes

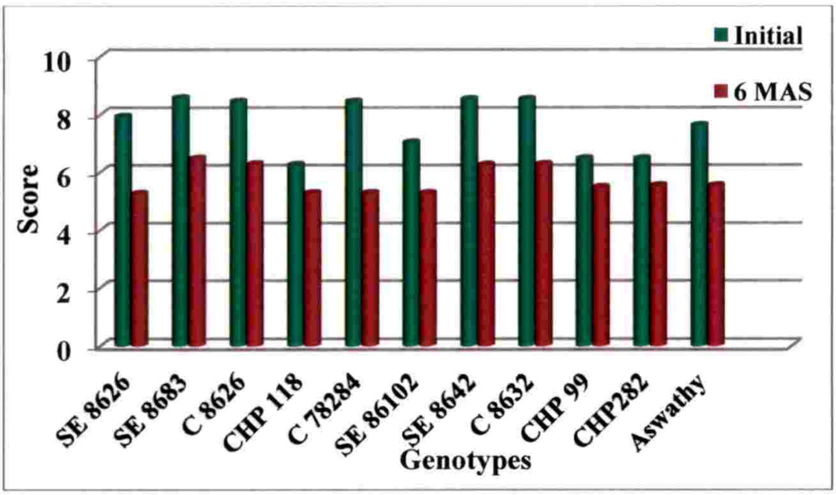

Fig 22. Sensory score of ginger powder

(MAS – Months After Storage)

acidity ginger powder decreased during storage and at final stage of storage, titratable acidity of ginger powder ranged from 0.10 to 0.80%. The acid present in the product prepared is utilized for hydrolysis of polysaccharides for converting non-reducing sugar to reducing sugar that might lead to decreased acidity. In the present study, the maximum titratable acidity (0.80 %) was registered in somaclones SE 8626 and CHP 282 (0.80 %) followed by SE 8683 and CHP 118 (0.79 %). The minimum value was observed in Aswathy (0.10 %).

5. 4.5.3 Microbial population of ginger powder

In ginger powder, no bacterial growth was detected in any of the somaclones immediately after preparation and also at 2 and 4 MAS. However it was found in the somaclones SE 8642 (3.00 X 10^{-5}) and CHP 282 (4.30 X 10^{-5}) after 6 months of storage (Table 26). No mould and yeast growth detected in ginger powder of different somaclones from initial to final period of storage study. Drying and powdering is one of the widely used methods of preservation and it assures microbial stability of the product and reduces physical and chemical changes during storage (Lewicki and Lenart, 1992).

5.4.5.4 Sensory evaluation

Total score for ginger flakes from different genotypes at initial stage ranged from 43.94 to 65.28. Powder from somaclone SE 8683 was identified as the best sample as its score for appearance, colour, flavor, texture, odour, taste, after taste, overall acceptability and total score was the highest (65.28) compared to other somaclones, followed by SE 8642 (63.76), C 8626 (62.76) and C 8626 (61.13). Powder from CHP 118 was considered the least preferred since its score for appearance, colour, flavor, texture, odour, taste, after taste, and overall acceptability contributing to total score, was the lowest (43.94). Other acceptable somaclones are SE 8626, CHP 99 and Aswathy

Sensory score of ginger powder from different genotypes showed a declining trend during storage. But at final stage of storage also, somaclones such

Initial


Bacteria x 10^{-5}


Mould x 10^{-2}


Yeast x 10^{-3}

6 months after storage


Bacteria x 10^{-5}


Mould x 10^{-2}


Yeast x 10^{-3}

Plate 11. Microbial load in ginger candy

as SE 8683 (58.44), SE 8642 (58.17) and C 8626 (58.02) showed total score more than 50 and are under acceptable limits based on the sensory scores (Figure 22).

SE 8683

SE 8642

C 8626

Plate 13. Ginger somaclones selected for value addition

SUMMARY

6. SUMMARY

Investigation on screening ginger (*Zingiber officinale* Rosc.) genotypes under different growing conditions and for value addition was carried out at the Department of Plantation Crops and Spices, College of Horticulture, Vellanikkara during 2015-18 to evaluate somaclones for yield and quality attributes, suitability for growing under different growing conditions and for value addition.

The salient findings of the above study are summarized in this chapter.

Expt 1. Screening ginger genotypes for yield and quality

- Among the fourteen genotypes evaluated, early sprouting (13.97 days) was observed in Aswathy whereas sprouting was late in CHP 99 (23.67 days). Days for sprouting were more than 20 in C 8626, SE 8642, CHP 282 and CHP 99.
- Plant height was maximum in SE 86102 at 4 and 6 months after planting (103.80 and 107.38 respectively), whereas, Aswathy recorded lowest plant height.
- Number of tillers was maximum in CHP118 at 4 and 6 months stage. At 6 months stage, tillers were more than 16 in SE 8626 (18.01), CHP 118 (20.33), SE 8642 (17.97) and C 8632 (16.93).
- Number of leaves per shoot (28.67) and per plant (117.38) was the highest in CHP 118 and was on par with SE 8626 (28.33 and 108.33 respectively).
- Leaf area increased from 2 to 4 months stage and later decreased. Leaf area was the highest in CHP 118 at 4 months stage and C 8632 at 6 months stage.
- The number of primary rhizomes was high in CHP 118 (4.83), SE 8626 (4.33) and C 8632 (4.08). CHP 118 (10.33), SE 8626 (10.06) and C 8632 (10.01) recorded more number of secondary rhizomes (>10). The number of tertiary rhizomes was also found maximum for CHP 118 (17.00).

Quaternary rhizomes number was maximum in SE 8626 (12.67) and was on par with CHP 118 (10.67) and SE 8683 (9.33), whereas CHP 99.

- The weight of mother rhizome varied from 5.60g (Rio- de-Janeiro) to 11.00 g (SE 8642). Weight of primary rhizome significantly differed among the somaclones with higher values in SE 86 42 (15.73 g), SE 8626 (15.07 g), CHP 118 (14.80 g) and C 8632 (14.01 g).Secondary rhizome weight was higher in SE 8626 (13.20 g) and SE 86 42 (12.33 g).
- Higher values for the length of primary rhizomes were recorded in CHP 118 (3.80 cm), SE 8626 (3.67 cm), SE 8683 (3.43 cm) and C 8632 (3.41 cm). SE 8626 (3.57 cm), CHP 118 (3.52 cm) and C 8632 (3.34 cm) recorded higher values for secondary rhizome length also.
- Higher values for girth of primary rhizomes were recorded in the somaclone SE 8626 (9.20 cm), SE 8642 (9.07 cm), CHP 118 (8.57 cm) and C 8632 (8.57 cm). Girth of secondary rhizomes ranged from 5.67 cm (SE 86102) to 9.07 cm (CHP 118).
- The fresh rhizome yield was more than 250 g per plant in four somaclones *viz.*, CHP 118 (274.13 g), SE 8626 (266.67 g), C 8632 (259.67 g) and SE 8642 (251.67 g). Yield was found to be significantly correlated with number of tillers, number and weight of rhizomes. The highest yield per plot (8.77 kg) was recorded in CHP 118 followed by SE 86 26 (8.54 kg), C 8632 (8.31 kg) and SE 8642 (8.06 kg). Four somaclones namely, CHP 118 (35.08 t), SE 86 26 (34.16 t), C 8632 (33.24 t) and SE 8642 (32.24 t) were identified as high yielders with more than 30 t/ha, whereas the check varieties yielded only 24-25 t/ha in this study.
- Driage and dry yield was the highest in SE 8626. Dry recovery or driage of the rhizomes ranged from 13.56 % (CHP 282) to as high as 23.18 % (SE 8626). Driage was more than 20 percentage in two somaclones namely SE 8626 (23.18 %) and SE 8642 (21.20%). Dry yield per hectare was more than 5 tonnes in four somaclones namely SE 8626 (7.92 t), CHP 118 (6.92 t), SE 8642 (6.84 t) and C 8632 (5.96).

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- Among the quality parameters , volatile oil content was higher (> 3%) in CHP 118 , SE 8626 (3.30 %). Volatile oil content of check varieties were fairly high ranging from 2.90 % (Aswathy) to 3.02 % (Rio-de-Janeiro).
- All the check varieties (Rio-de-Janeiro, Himachal and Aswathy) are having higher content of oleoresin (> 6%), whereas among somaclones, only four namely, SE 8626, CHP 118, C 78284 and CHP 282 were found to possess high oleoresin (> 6%) content.
- Crude fibre content varied from 2.13 % (C 8626) to 4.03% (SE 8626) at five months maturity. Low fibre content (<2.5%) was recorded in SE 8683, C 8626, C 78284 and SE 8642.
- Chemoprofiling of oleoresin revealed high content of (6)- Gingerol, (8) – Gingerol, (10)- Gingerol and total gingerol in Rio-de-Janeiro (1.20%, 0.14 % , 0.14 % and 1.48 % respectively). The total shogaol content was the highest in CHP 282 (0.16 %) followed by Rio-de-Janeiro (0.11 %) and SE 8642 (0.10 %).
- Among the physiological parameters observed, chlorophyll index value was recorded maximum for Himachal (45.25) followed by CHP 99 (43.58) and the lowest was for the somaclone C 86 26 (36.02) at six months maturity.
- The photosynthetic rate was recorded maximum for the somaclone SE 8642 (20.13 μmol $m^{-2}sec^{-1}$) and the lowest was for Rio-de-Janeiro (11.00 μmol $m^{-2}sec^{-1}$) at six months maturity.
- The transpiration rate was recorded maximum for the somaclone SE 8642 (1.56 μmol $m^{-2}sec^{-1}$) and the lowest was for CHP 99 (0.63 μmol $m^{-2}sec^{-1}$) at six months maturity.
- Lowest incidence of shoot borer was noticed in somaclones CHP 282 (3.13 %), SE 8626 (4.79 %), C 8632 (5.21 %), CHP 118, CHP 99 and SE 86102 with a value of 6.25 % incidence. However it was more in check variety Aswathy (28.13 %) at 6 months stage.
- Somaclones SE 8683, CHP 118, C 8632 and Aswathy recorded minor incidence of rhizome rot with a value of 3.13 %. Other somaclones such as

SE 8642 (4.17 %), SE 8626 (4.79 %) and C 8626 (4.79 %) recorded less than 5 % incidence.

Expt 2. Performance of ginger genotypes under different growing conditions

- The number of days for sprouting of the genotypes ranged from 13.67 days to 16.25 days under open field condition whereas under rain shelter, sprouting was found early (11.50 to 15.75 days). Early sprouting was observed in somaclone SEHP 9 (14.51 days) and check variety Aswathy (13.67 days) under open field , whereas in rain shelter early sprouting was observed in SE 8640 (11.50 days).
- At initial stages (2 to 5 months), plant height was higher in all genotypes under in rain shelter, whereas at 6 months stage, plant height was higher and more than 90 cm in SE 8681 and SE 8640 under open field condition. Under rain shelter condition, plant height was more than 80 cm in all the somaclones except Aswathy with the highest value in SEHP 9 (88.78 cm) and SE 8640 (87.84 cm).
- Number of tillers produced by ginger somaclones were less in rain shelter condition at all growth stages. Under open field condition, at six months stage, the number ranged from 14.69 (Aswathy) to 17.09 (SEHP 9). Under rain shelter condition, SEHP 9 (7.80), SE 8681 (7.20), SE 8640 (6.90) and SE 86131 (6.70) recorded higher values for the tiller number. Among the somaclone, SEHP 9 recorded the highest number of tillers irrespective of the growing conditions.
- Number of leaves per shoot and per plant was higher in open field condition in all the genotypes. Somaclone SE 8640 recorded highest number of leaves per shoot and plant both in open field (23.10 and 87.00 respectively) and rain shelter conditions (20.23 and 82.25 respectively) at 6 months stage followed by SEHP 9.

- Leaf area increased with age of the plant and reached maximum at 5 month and later decreased. Leaf area was found higher in open field than in rain shelter. Leaf area was found to be the highest for the somaclone SE 8640 and SEHP 9 at 5 months stage both under open field condition and the and rain shelter.
- Yield was higher in open field than in rain shelter and among the genotypes, yield per hectare was more than 25 tonnes in three somaclones namely SEHP 9 (32.48 t), SE 8681 (28. 56 t) and SE 8640 (27.28 t). Even under rain shelter, the same three genotypes yielded more than 20 tonnes per hectare with highest value in SE 8640 (25. 24 t). SE 8640 is identified for rain shelter cultivation based on this study.
- Driage was not significantly influenced by the growing conditions. Dry yield was higher in SEHP 9 (7.24 t/ha) and SE 8681 (6.06 t/ha) under open field indicating their suitability for dry ginger purpose.
- Chlorophyll index (4 months stage) under open field condition ranged from 42.29 (Aswathy) to 50.78 (SEHP 9), whereas in rain shelter SE 8640 registered the highest value of 52.00 which was on par with SE 8681 (50.70) and SEHP 9 (50.63).
- Higher mean photosynthetic efficiency was noticed at 4 months stage under open field condition (23.92 μmol $m^{-2}sec^{-1}$) than rain shelter (18.80 μmol $m^{-2}sec^{-1}$). Among the somaclones, SEHP 9 and SE 8640 recorded maximum mean values (23 μmol $m^{-2}sec^{-1}$) for photosynthetic rate irrespective of growing conditions.
- The transpiration rate was high in open condition and it is varied from 3.98 μmol $m^{-2}sec^{-1}$ (Aswathy) to 4.99 μmol $m^{-2}sec^{-1}$ (SE 86 81) during 4 months stage and in rain shelter, SE 8640 (3.64 μmol $m^{-2}sec^{-1}$) and SE 8681(3.18) recorded higher values.
- Stomatal conductance during 4 MAP, varied from 0.08 m μmol $m^{-2}sec^{-1}$ (Aswathy) to 0.27 m μmol $m^{-2}sec^{-1}$ (SEHP 9) under open field. There was no significant difference among the somaclones on stomatal conductance under rain shelter condition.

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- Incidences of pest and disease was less under rain shelter condition compared to open field. Among the somaclones, SEHP 9 showed minor attack of stem borer and rhizome rot under both the growing conditions.

Expt 3. Quality profiling under different growing conditions and different maturity stages.

- Quality parameters like volatile oil and oleoresin content did not differ significantly under different growing conditions though slightly higher values were observed in rain shelter condition. SE 8640 recorded the highest volatile oil content under both growing conditions (open field - 4.45 % and rain shelter -4.67 %) followed by Aswathy (3.50 % - open field and 3.63 % in rain shelter) at 5 months stage. Volatile oil content was found to decrease with advancement in growth stages (7 months stage).
- SEHP 9 recorded higher value for oleroresin content under both growing conditions (6.01 %- open field and 6.72 %- rain shelter) at 5 months stage. At 7 months stage Aswathy recorded the highest value for this character (4.58 %- open field and 5.49 %- rain shelter)
- Crude fibre content increased with maturity in all genotypes and its content was low under rain shelter conditions. Lowest crude fibre content was recorded in SE 86131 (1.70 %) under open field condition, whereas in rain shelter SE 8681 registered the lowest value (1.46 %). At 7 months stage, under open field condition, SE 8640 registered the lowest value both under open field (2.45 %) and rain shelter (2.26 %).
- The Aswathy registered the highest value for total gingerol and shogaol content under both the growing conditions (1.46 % -open field and 1.02 % rain shelter) compared to the somaclones.

Expt 4. Screeing ginger genotypes for product preparation

- At five months maturity, somaclones exhibited difference in easiness for peeling and peeling was very easy in four somaclones SE 8626, SE 8683, SE 86102 and CHP 282. At seven months maturity, only SE 8683 was found to be much easy to peel compared to somaclones and the variety Aswathy.
- SE 8642 (78.41) and C 8626 (78.24 %) recorded the highest recovery for candy. SE 8626 recorded significantly the highest value of flakes recovery (18.21 %) followed by C 8626 (16.80 %). The recovery of ginger powder was the highest in SE 8642 (18.21 %) compared to others.
- Screening for value added products revealed the suitability of ginger somaclones for preparation of ginger candy, flakes and powder based on physical and biochemical parameters of the products and sensory evaluation.
- In the storage study, moisture content and TSS of ginger candy samples was found to decreased, whereas titratable acidity increased and thereby lowering the pH of the samples. In the case of ginger flakes, moisture content increased with storage, whereas titratable acidity of the samples decreased and pH increased over the period. Moisture content of ginger powder showed increasing trend during storage, titratable acidity of the samples decreased and pH increased with storage.
- The colour of the products exhibited slight change only after four months of storage and microbial population was noticed only during six months of storage indicating the storage stability of the product.
- Based on overall acceptability score observed at initial and final stage of storage, the somaclones selected for candy preparation are SE 86 42, C 86 26 and SE 86 83. SE 8683, C8626, SE8642 and C 8632 for flakes and SE 8683, C 86 26, SE 86 42 and C 86 32 were found best among somaclones for ginger powder

- Three somaclones namely SE 8683, C 86 26 and SE 86 42 were found suitable for all the three value added products preparation

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APPENDICES

Appendix I: Weather parameters observed during crop period

a. Temperature under different growing conditions

Months	Open field		Rainshelter	
	Max. Temp (^{0}C)	Min.Temp(^{0}C)	Max. Temp(^{0}C)	Min.Temp(^{0}C)
May	28.0	26.71	30.7	28.4
June	27.3	26.5	31.6	28.7
July	27.4	25.5	27.5	26.3
August	29.7	27.7	29.8	28.0
September	30.6	27.0	28.5	27.0
October	28.8	27.2	29.3	27.7
November	29.3	26.0	30.6	27.8
December	29.1	27.1	29.2	27.1

b. Relative humidity under different growing conditions

Months	Relative Humidity (%)	
	Open field	Rainshelter
May	90.00	86.75
June	93.75	79.50
July	85.00	90.75
August	80.75	87.00
September	74.00	88.50
October	88.00	88.00
November	75.50	80.00
December	84.75	84.00

c. Light intensity under different growing conditions

Months	Light Intensity (Lux)	
	Open field	Rainshelter
May	1611	1262
June	1529	1347
July	1320	1154
August	1611	1262
September	1985	1980
October	1952	1605
November	1852	1386
December	1712	1320

d. Rain fall recorded during the crop period

Months	Rainfall (mm)
May	167.5
June	630.2
July	385.5
August	478.0
September	413.9
October	183.4
November	58.3
December	11.5

Appendix II. HPLC chromatogram of ginger somaclones

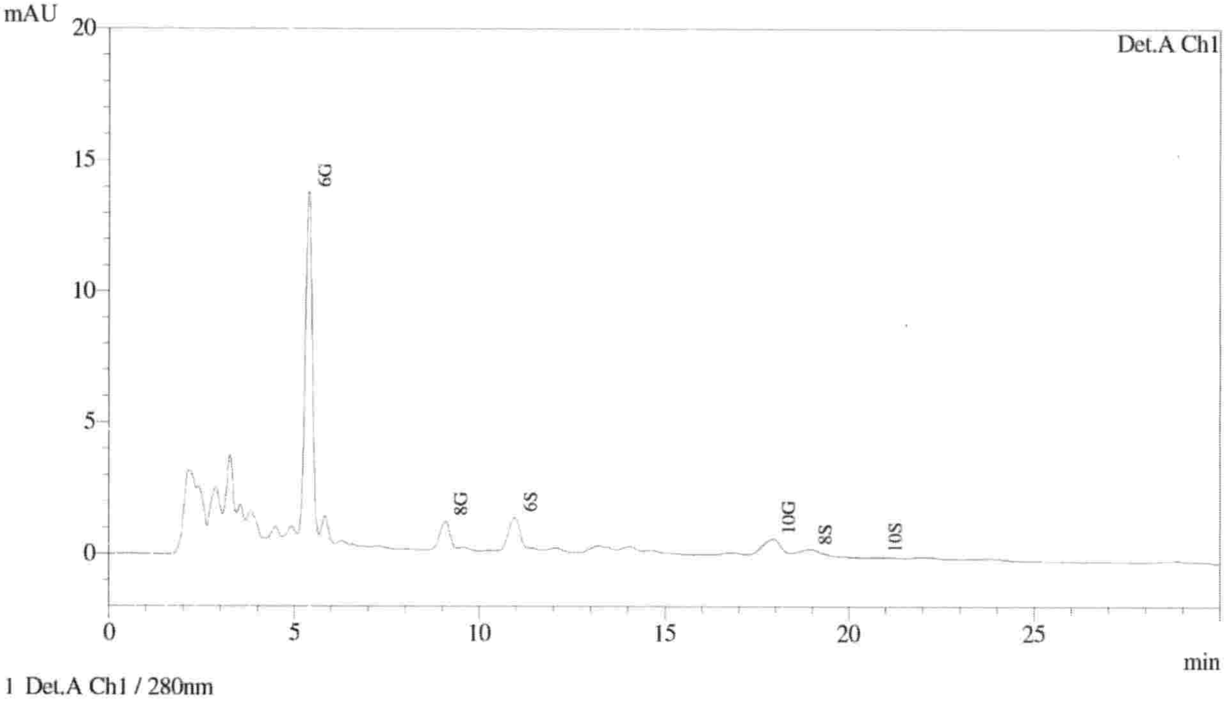

Fig1. HPLC chromatogram of somaclone SE 8626

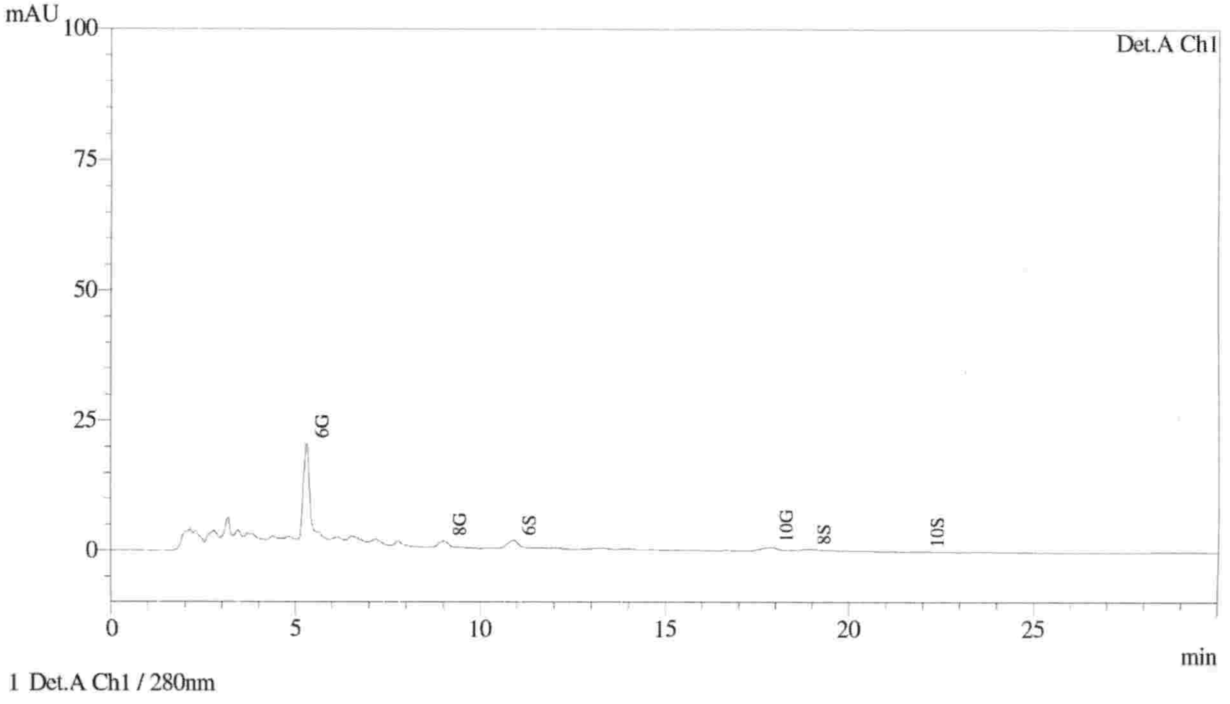

Fig2. HPLC chromatogram of somaclone SE 8683

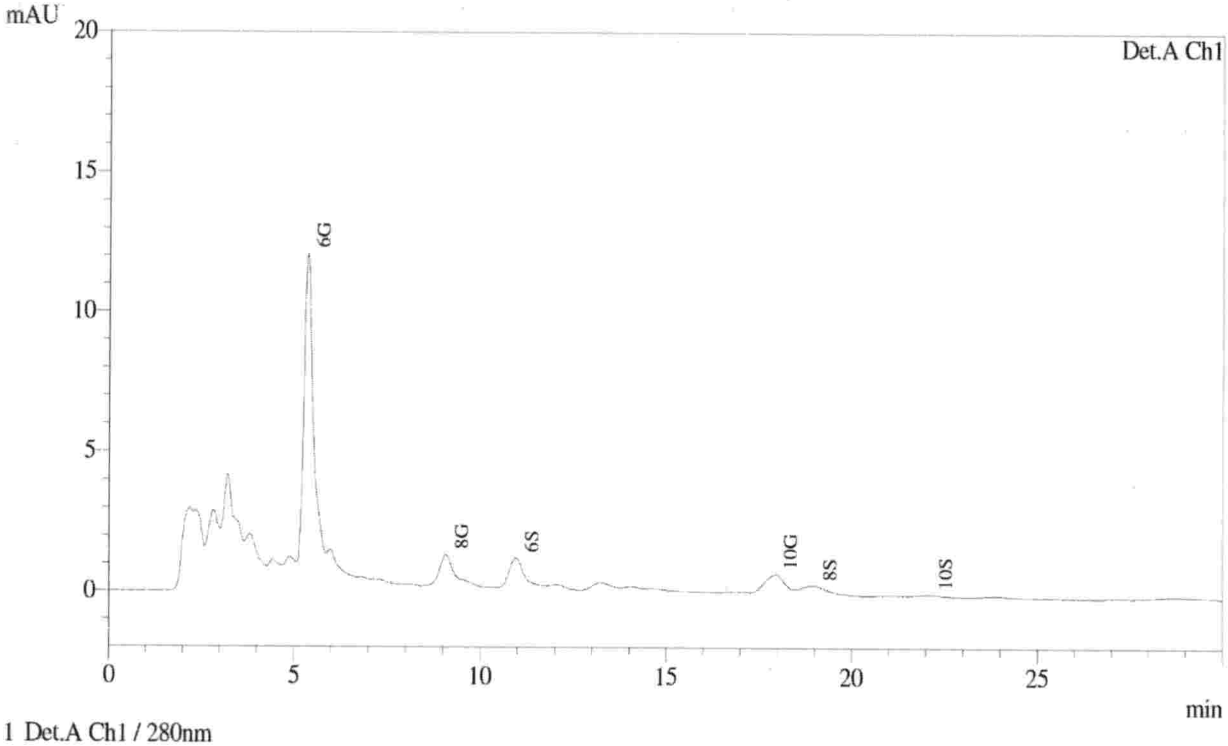

Fig3. HPLC chromatogram of somaclone C 8626

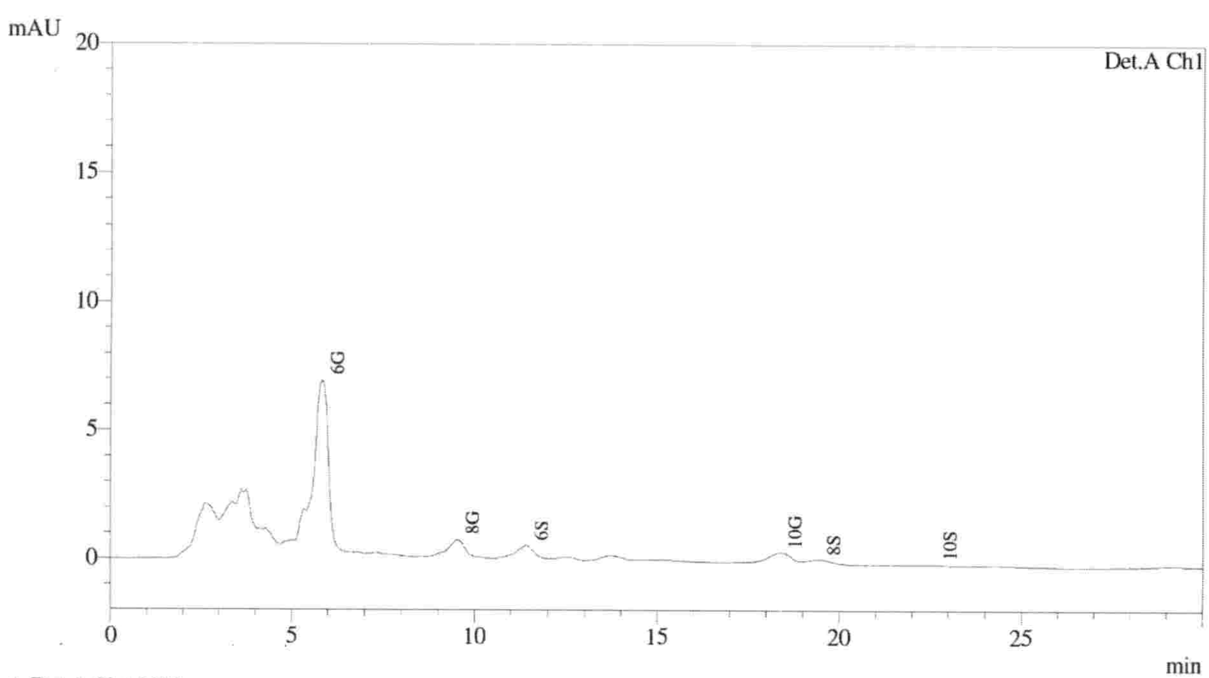

Fig4. HPLC chromatogram of somaclone CHP 118

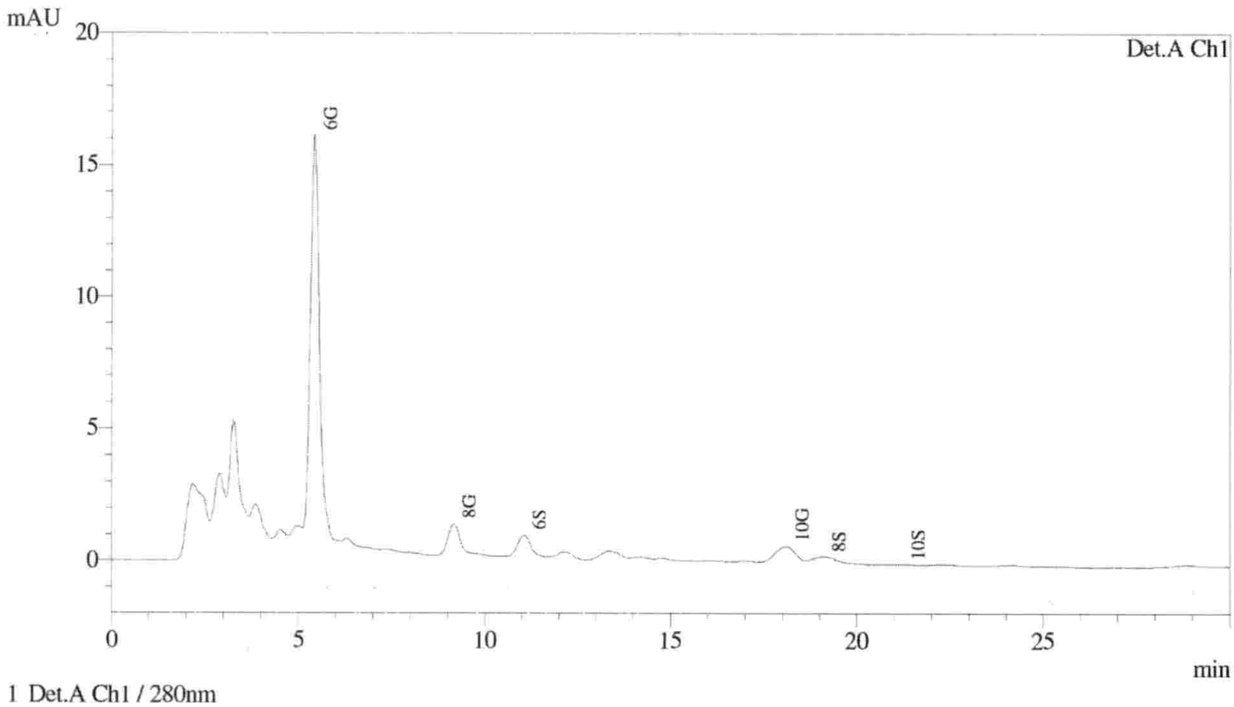

Fig5. HPLC chromatogram of somaclone C 78284

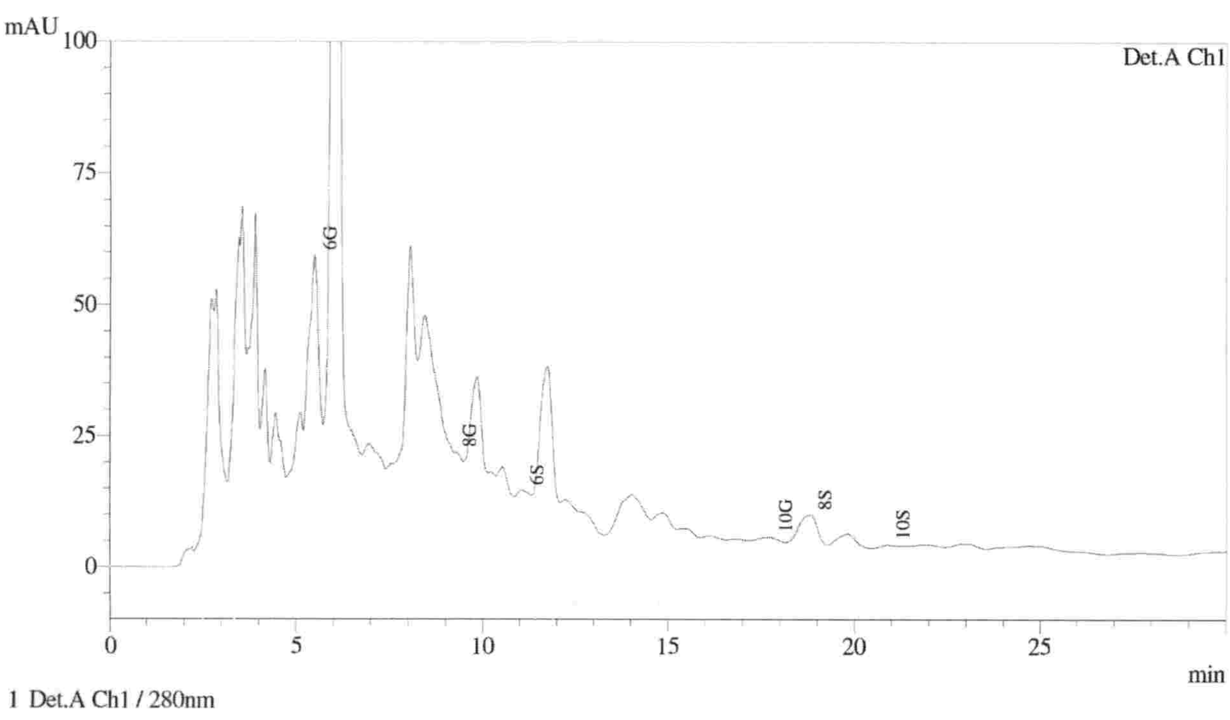

Fig6. HPLC chromatogram of somaclone SE 86102

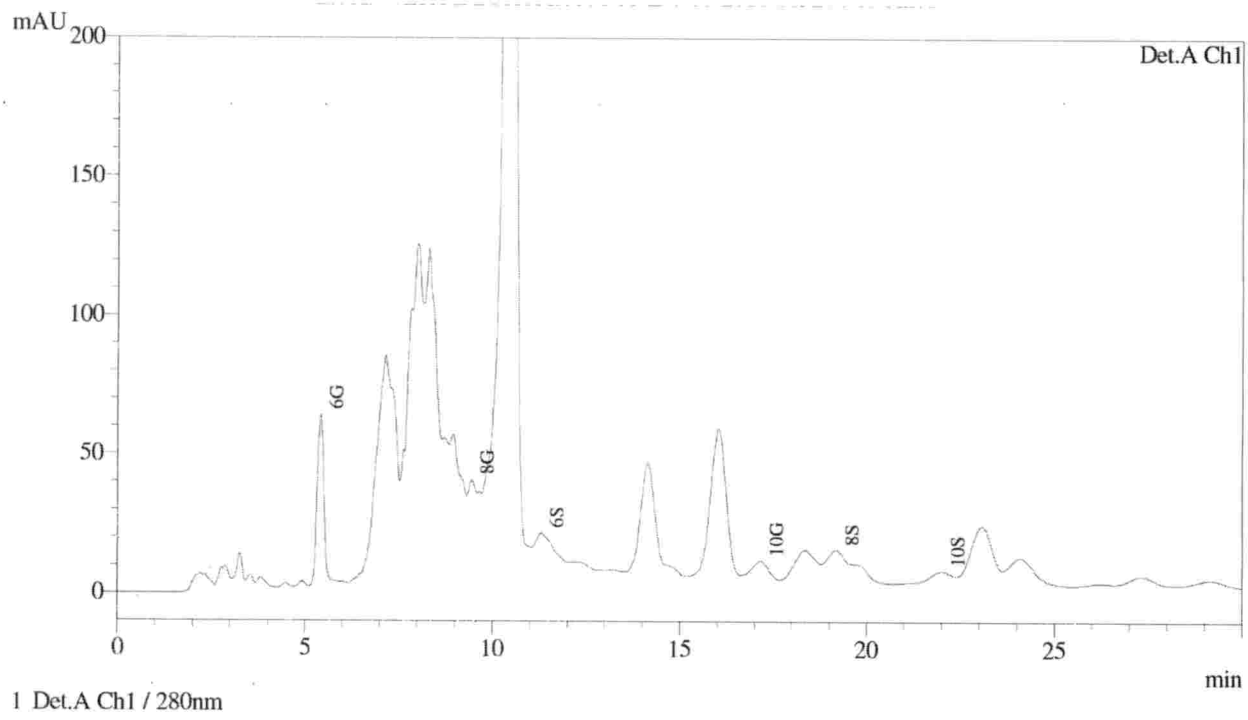

Fig7. HPLC chromatogram of somaclone SE 8642

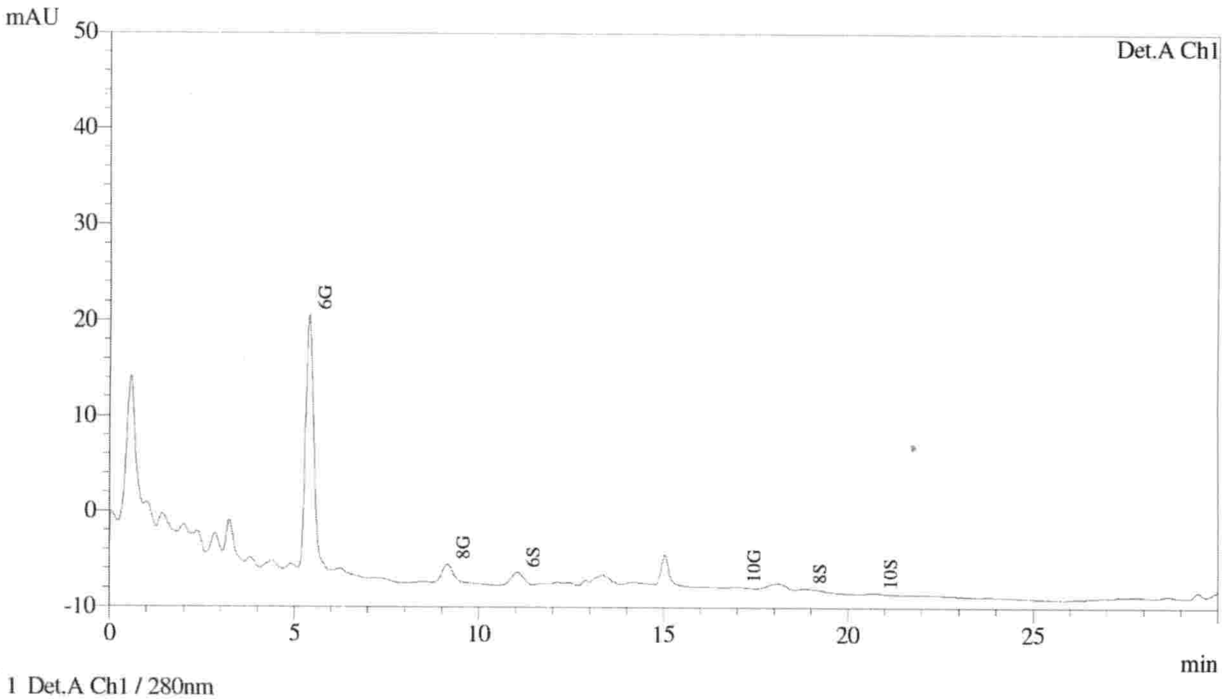

Fig8. HPLC chromatogram of somaclone C8632

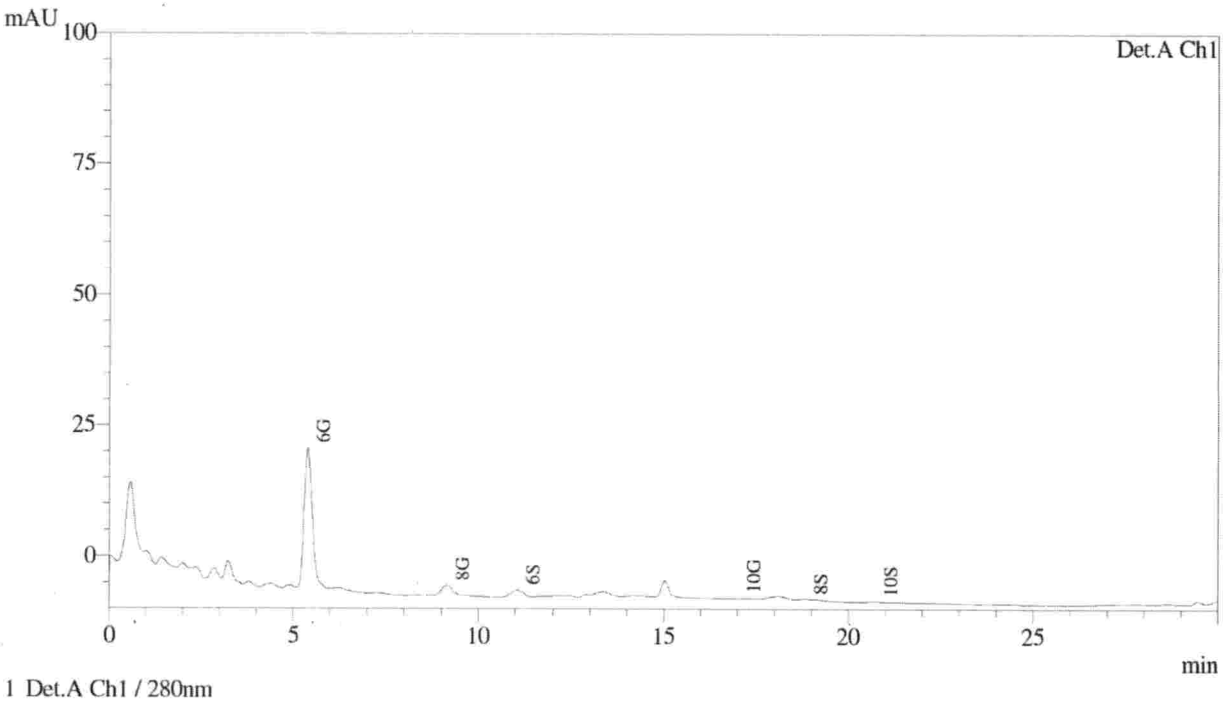

Fig9. HPLC chromatogram of somaclone CHP 99

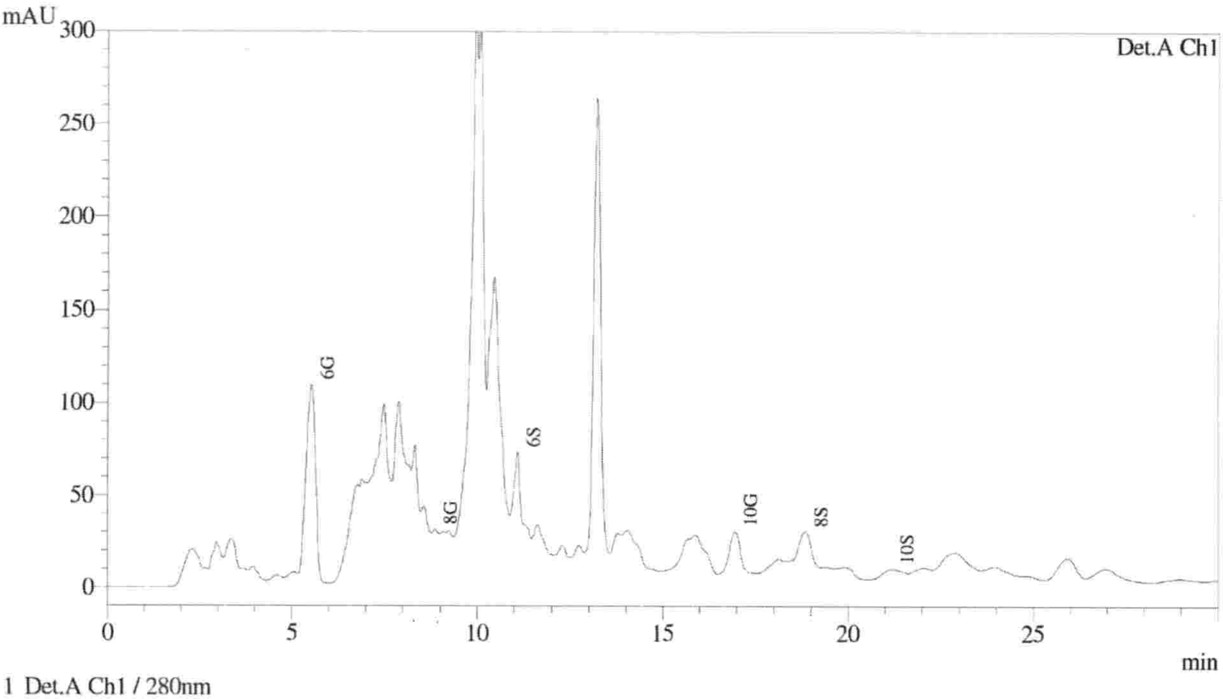

Fig10. HPLC chromatogram of somaclone CHP 282

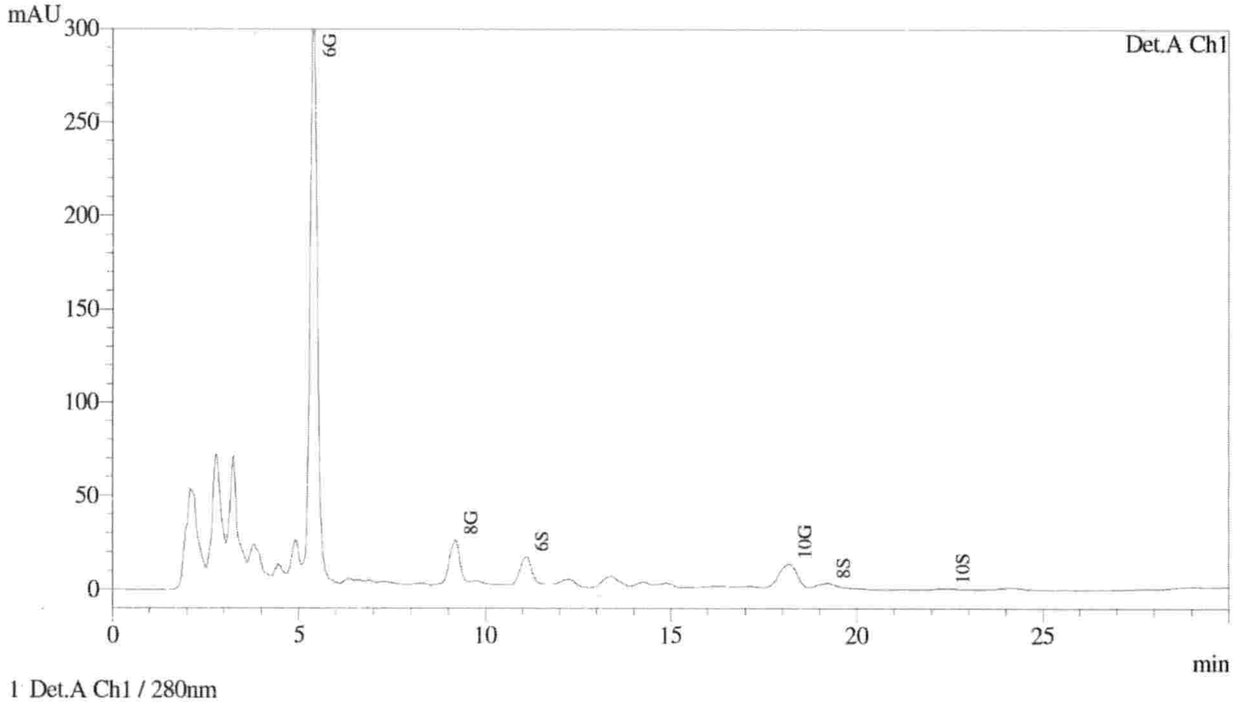

Fig11. HPLC chromatogram of variety Rio-de-Janeiro

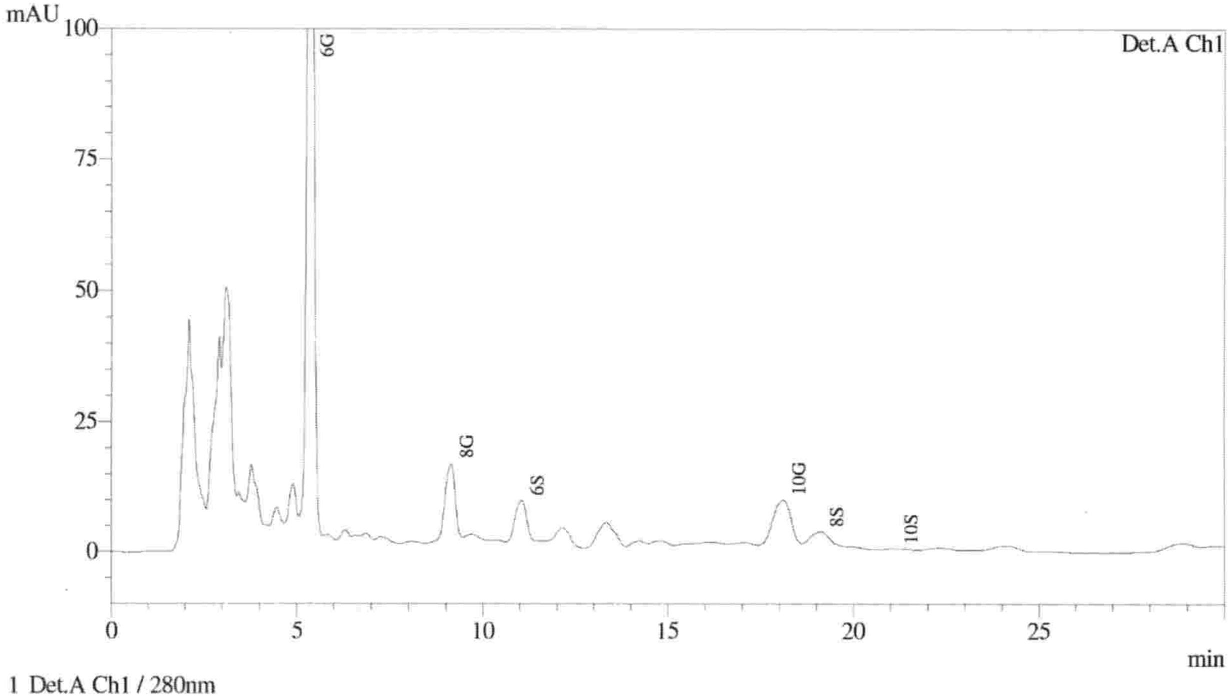

Fig12. HPLC chromatogram of variety Himachal

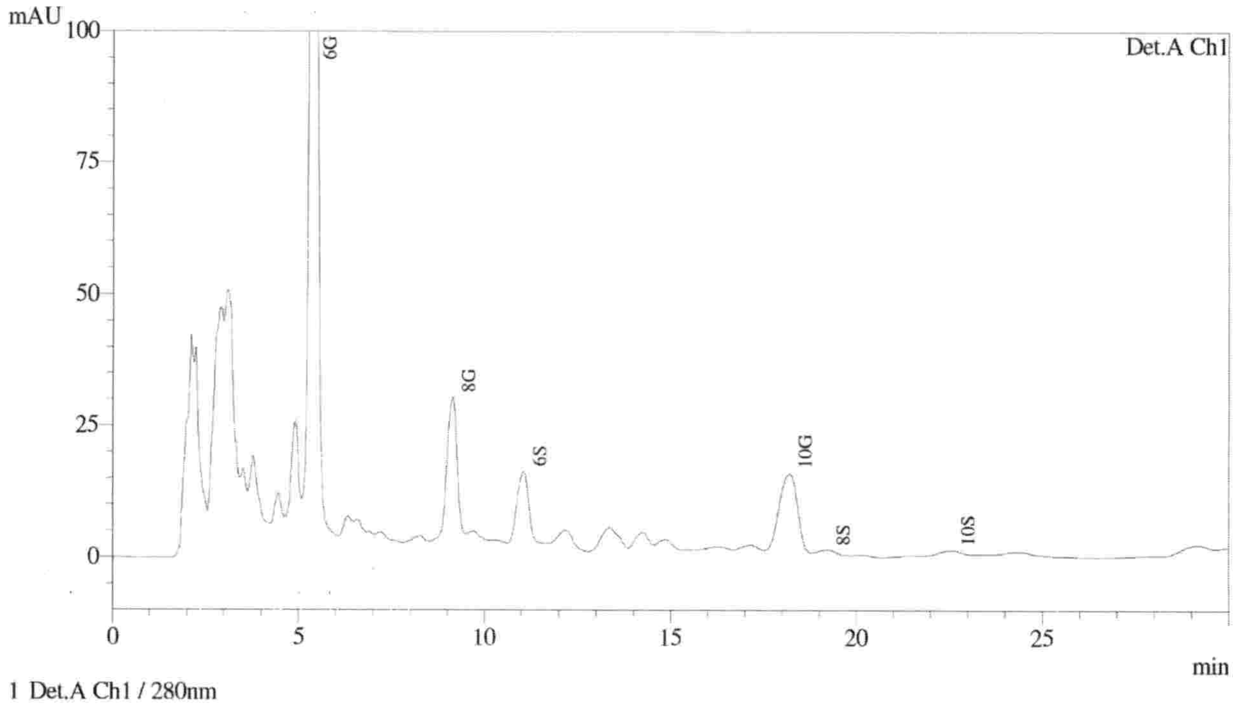

Fig13. HPLC chromatogram of variety Aswathy

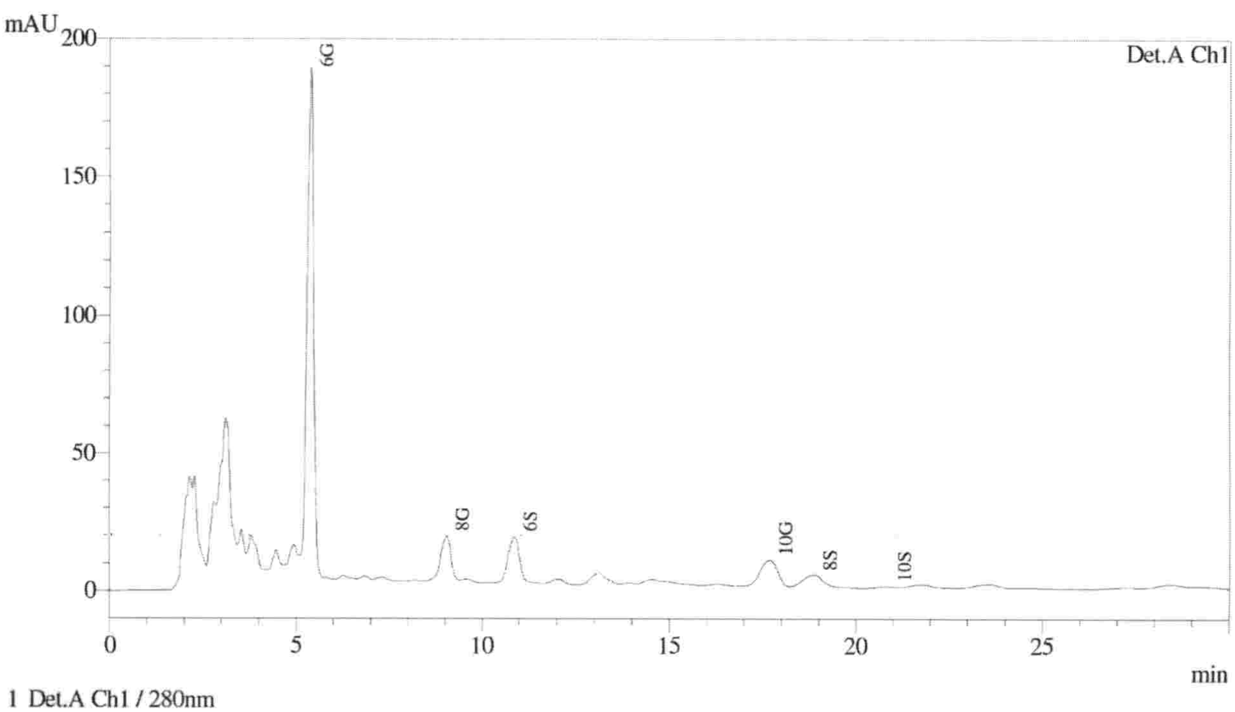

Fig14. HPLC chromatogram of somaclone SE 8681 (Open field)

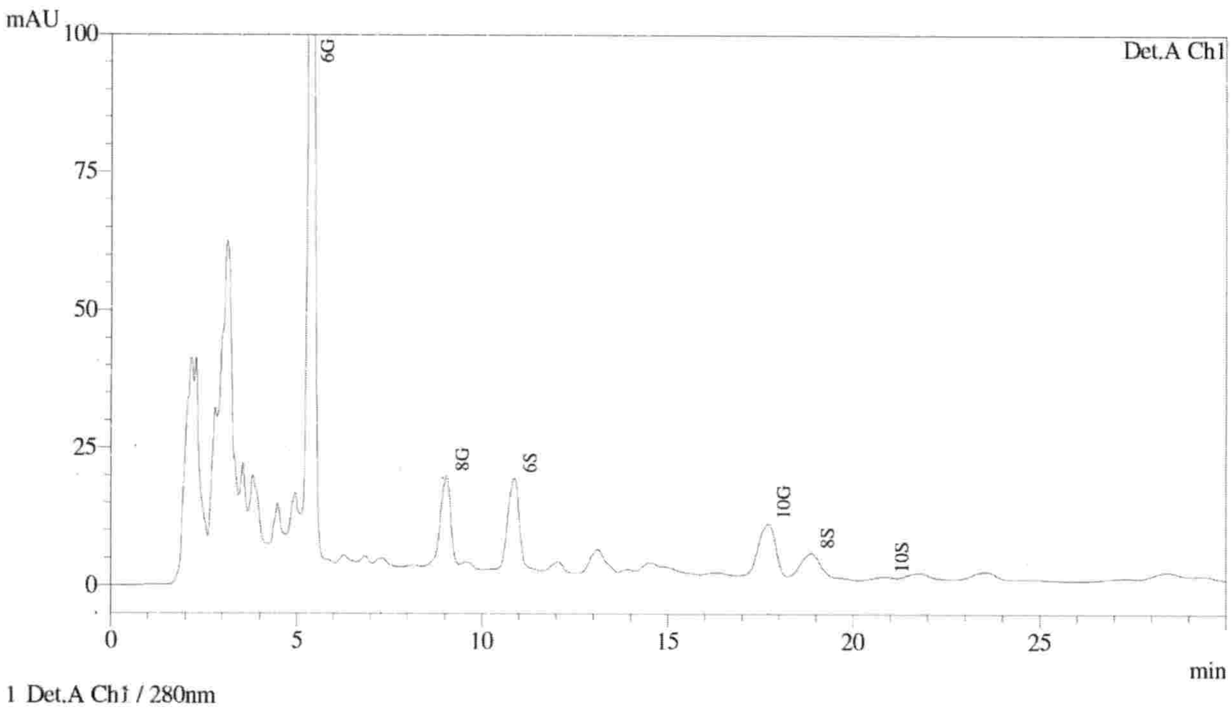

Fig15. HPLC chromatogram of somaclone SE 8640 (Open field)

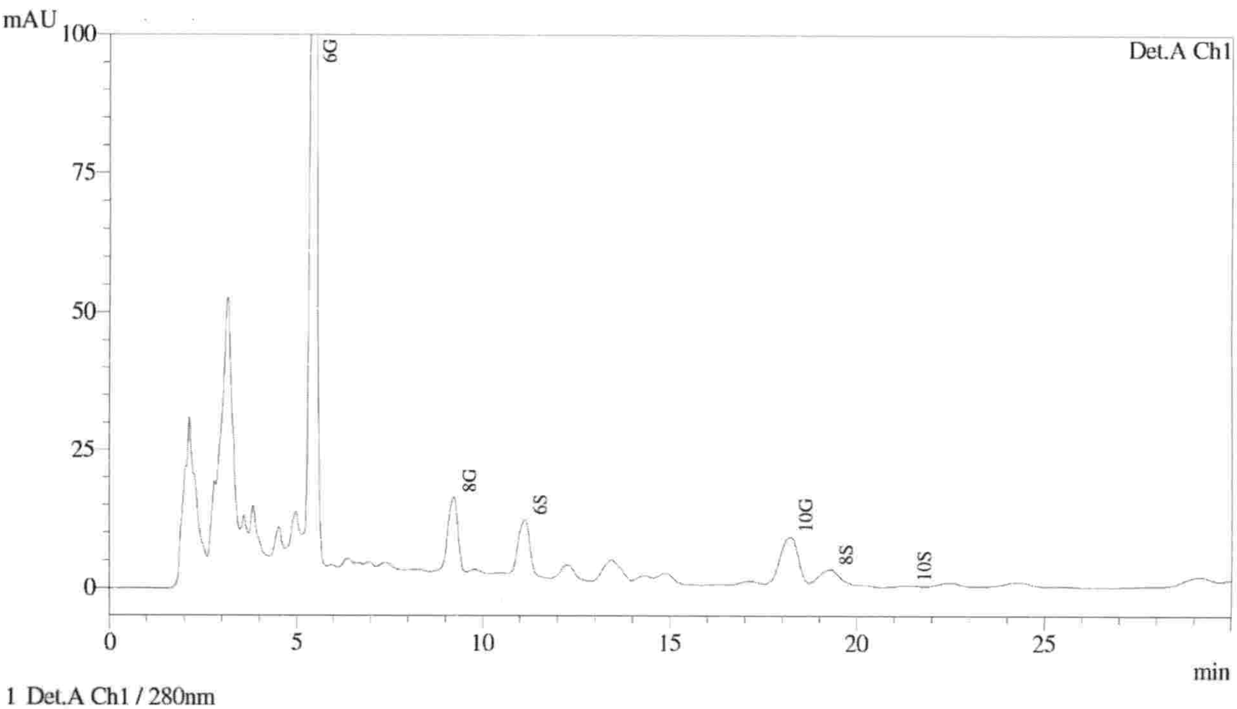

Fig16. HPLC chromatogram of somaclone SE 86131 (Open field)

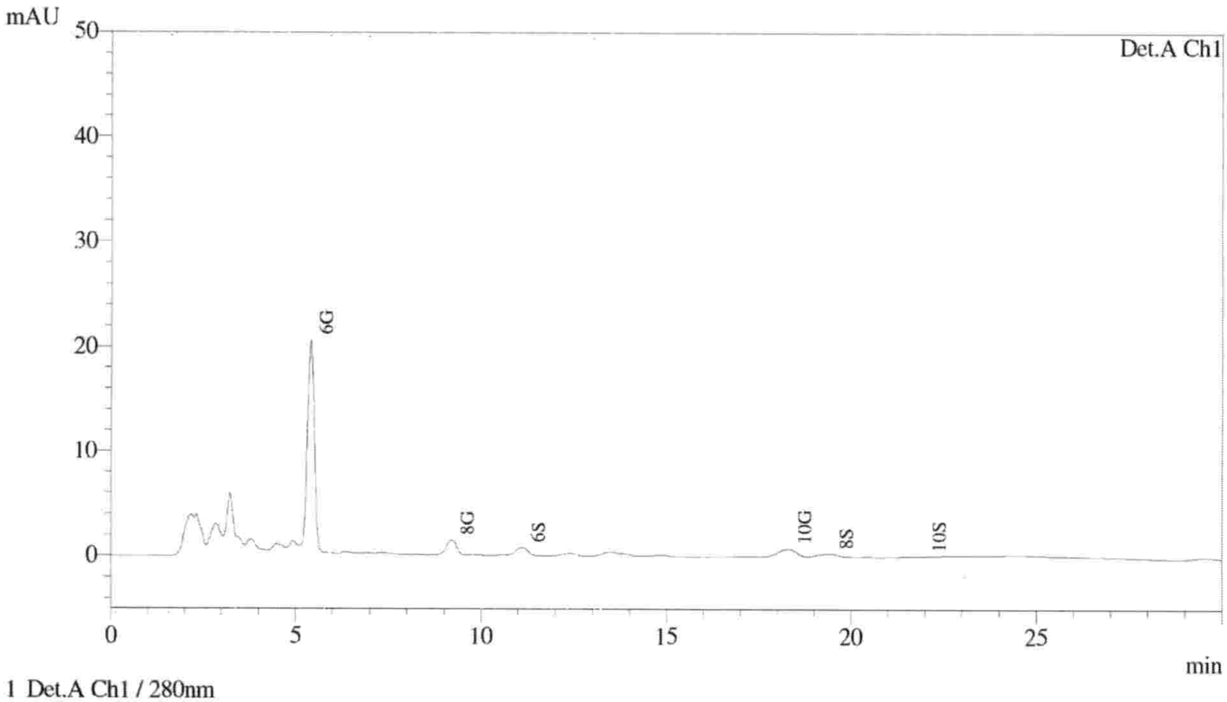

Fig17. HPLC chromatogram of somaclone SEHP 9 (Open field)

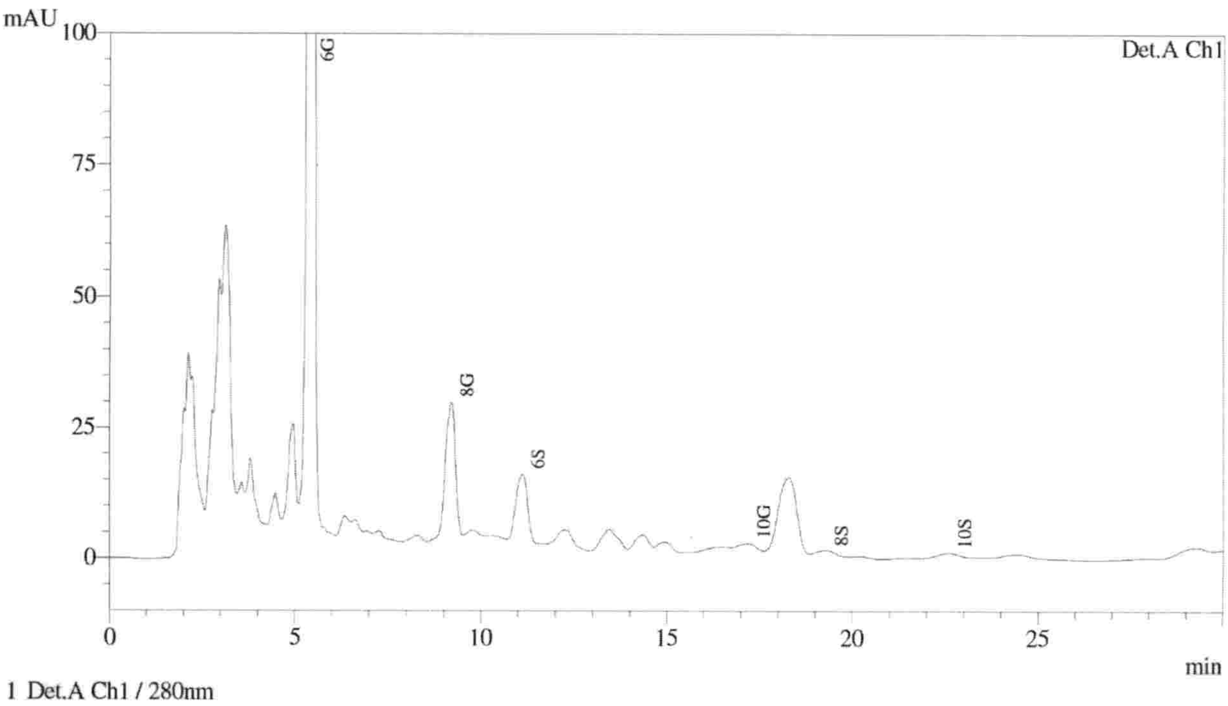

Fig18. HPLC chromatogram of variety Aswathy (Open field)

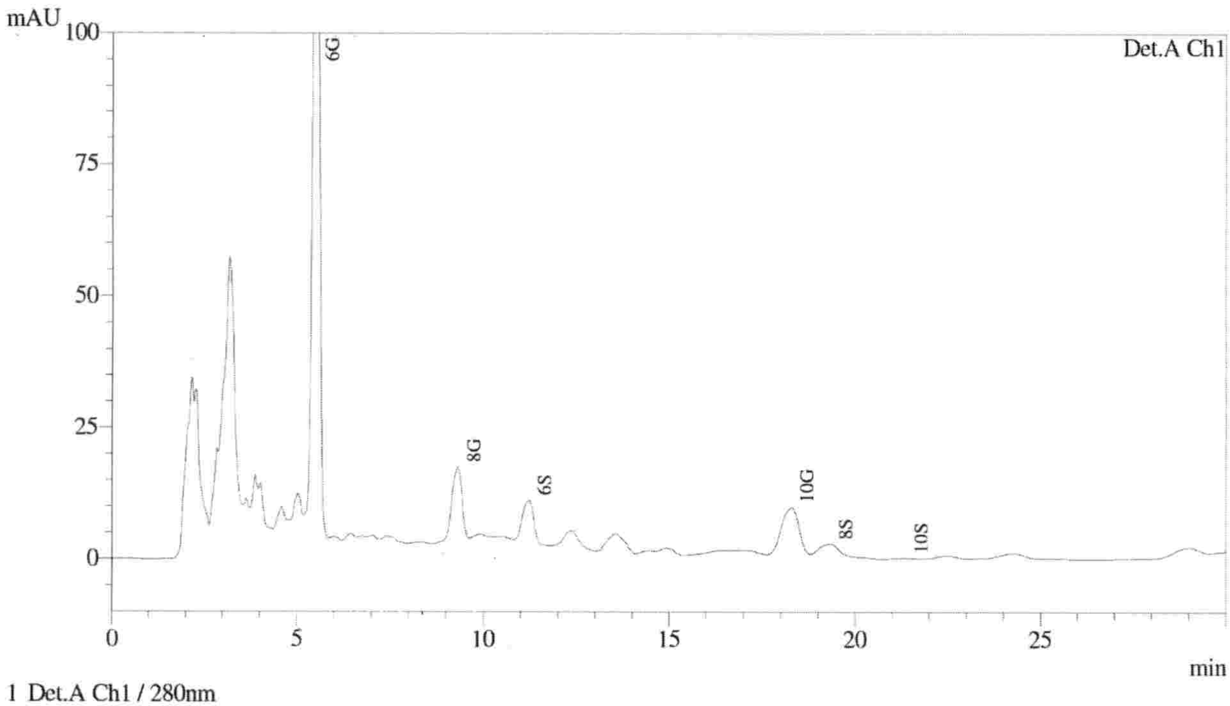

Fig19. HPLC chromatogram of somaclone SE 8681 (Rain shelter)

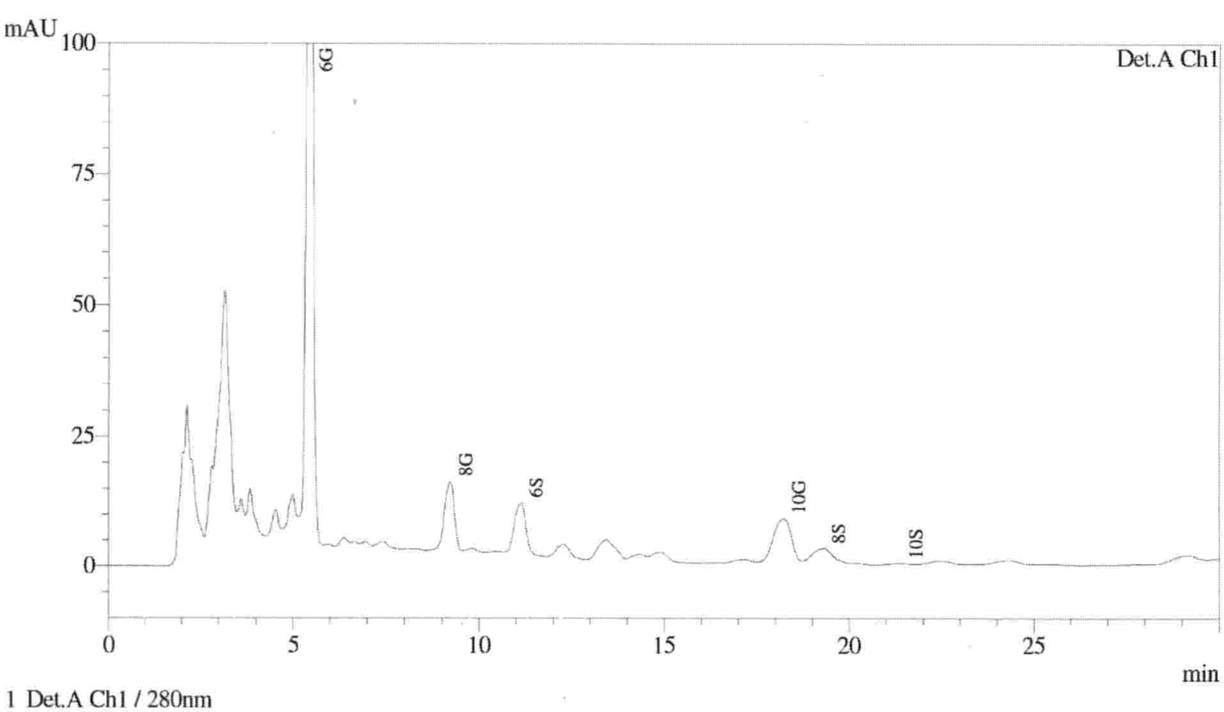

Fig20. HPLC chromatogram of somaclone SE 8640 (Rain shelter)

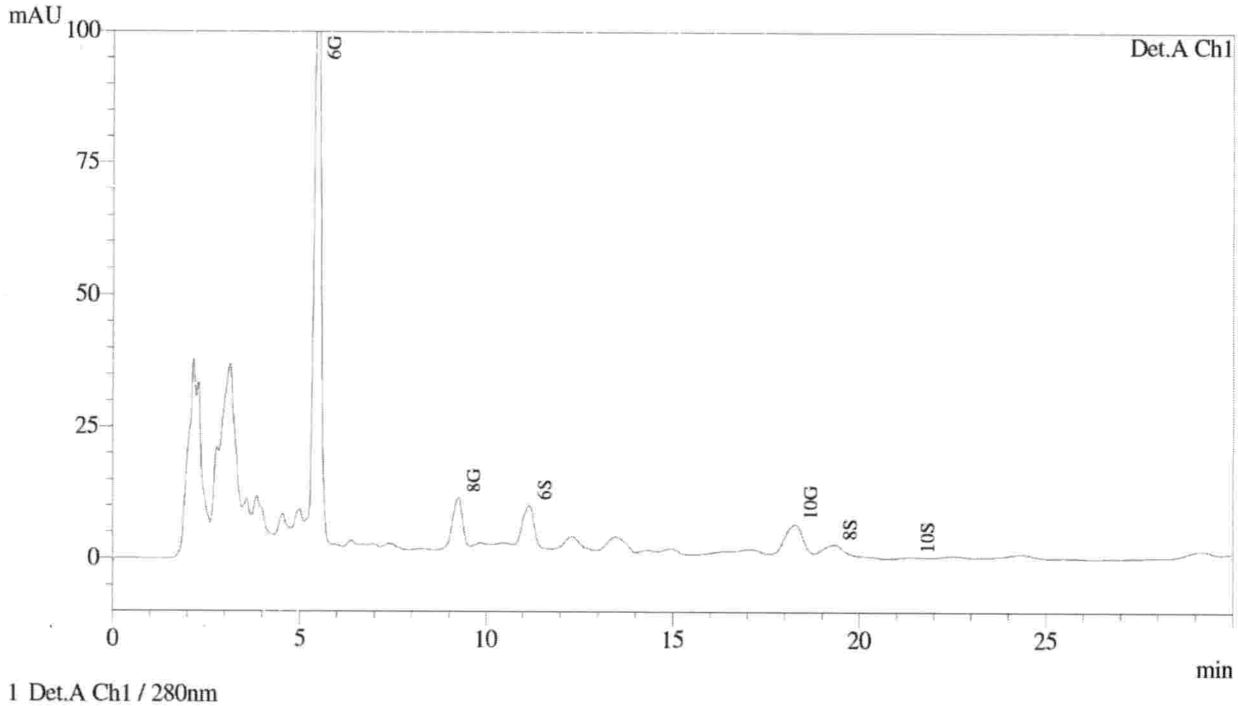

Fig21. HPLC chromatogram of somaclone SE 86131 (Rain shelter)

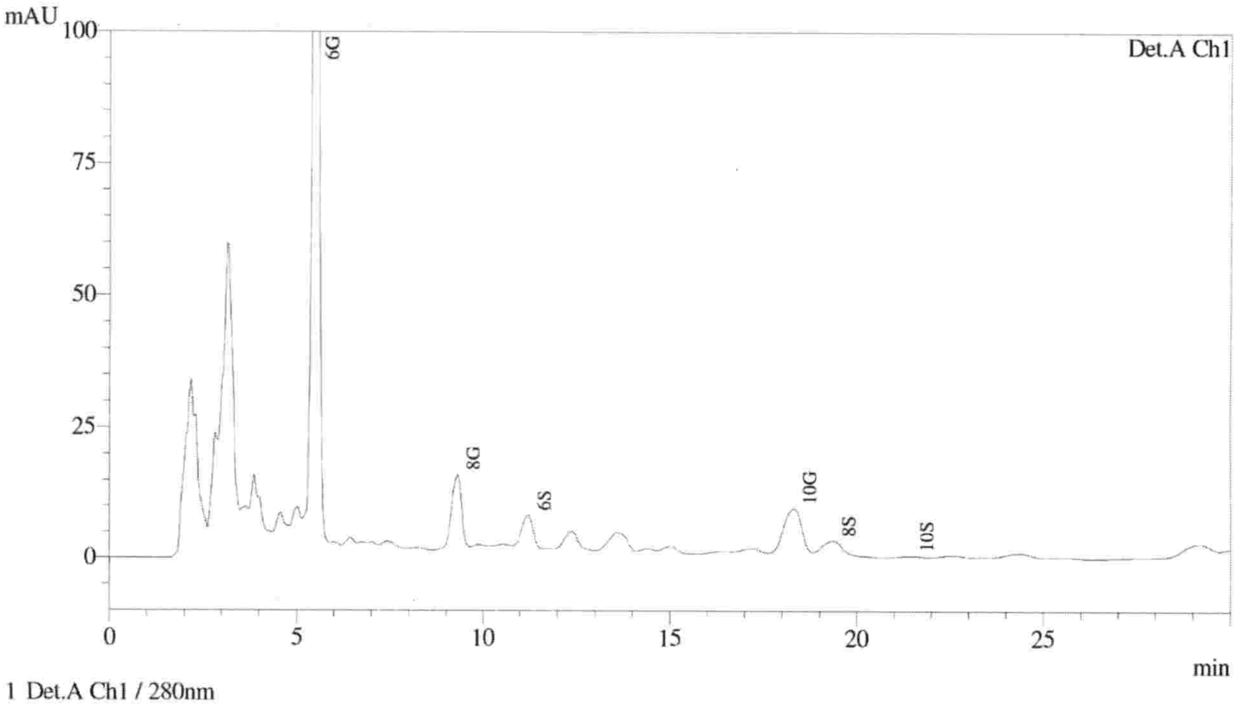

Fig22. HPLC chromatogram of somaclone SEHP 9 (Rain shelter)

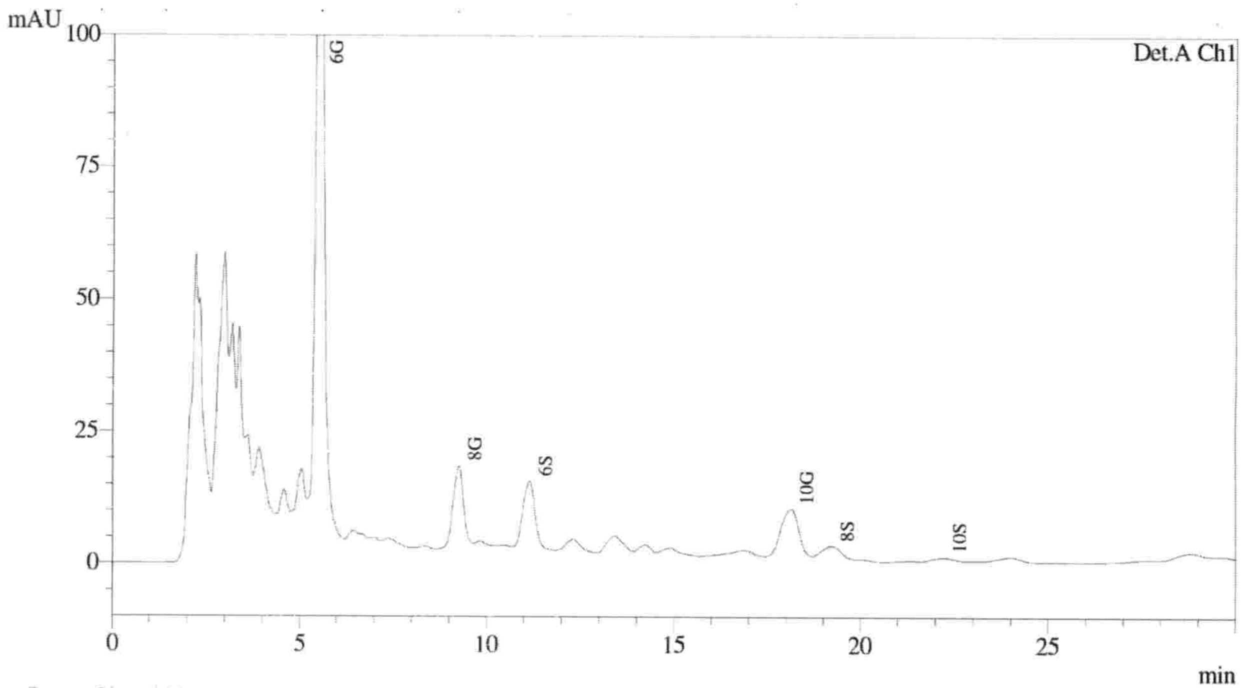

Fig23. HPLC chromatogram of variety Aswathy (Rain shelter)

Appendix III.

Table 1. Sensory scores of fresh ginger candy

Genotypes	Appearance	Colour	Flavour	Texture	Odour	Taste	After taste	Overall acceptability	Total score
SE 86 26	6.27	7.48	7.17	7.35	7.33	7.67	7.27	7.27	57.81
SE 86 83	6.40	7.63	7.27	7.43	7.77	8.10	8.15	8.23	60.98
C 8626	8.27	7.63	7.83	8.23	8.10	8.33	8.10	8.53	65.02
CHP 118	6.27	5.08	5.80	5.40	5.05	5.30	6.02	6.45	45.37
C 78 284	6.53	5.82	5.77	4.67	5.77	4.48	5.58	6.25	44.87
SE 86 102	7.33	6.03	6.23	5.37	6.23	6.33	5.90	7.03	50.45
SE 86 42	8.00	7.90	7.60	8.83	7.93	8.17	8.03	8.93	65.39
C 86 32	6.60	5.83	5.55	5.53	5.27	5.58	5.72	6.32	46.4
CHP 99	6.73	5.90	5.47	5.87	5.87	7.43	7.77	6.47	51.51
CHP282	6.80	5.93	5.70	5.63	5.37	5.87	5.73	6.47	47.5
Aswathy	6.27	5.75	5.37	5.77	5.77	7.28	6.32	7.62	50.15
Kendal's W test	0.438**	0.460**	0.426**	0.353**	0.389**	0.438**	0.028**	0.455**	

Table 2. Sensory scores of ginger candy after two months of storage

Genotypes	Appearance	Colour	Flavour	Texture	Odour	Taste	After taste	Overall acceptability	Total score
SE 86 26	6.05	7.30	7.00	7.27	7.00	7.55	7.00	7.00	56.17
SE 86 83	6.23	7.43	7.00	7.27	7.55	8.05	8.03	8.05	59.61
C 8626	8.05	7.00	7.33	7.55	8.05	8.15	8.05	8.03	62.21
CHP 118	6.25	5.05	5.35	5.35	4.60	5.05	8.00	8.03	47.68
C 78 284	6.40	5.30	5.75	4.48	5.37	4.65	5.37	6.33	43.65
SE 86 102	7.00	6.02	6.02	5.05	6.05	6.23	5.57	6.02	47.96
SE 86 42	7.55	7.55	7.55	8.83	7.77	8.03	7.77	7.00	62.05
C 86 32	6.40	5.53	5.53	5.37	5.15	5.37	5.27	7.62	46.24
CHP 99	6.73	5.90	5.47	5.87	5.87	7.43	7.77	6.33	51.37
CHP282	6.73	5.90	5.37	5.53	5.27	5.73	5.27	6.40	46.2
Aswathy	6.25	5.55	5.35	5.70	5.65	6.85	6.20	6.85	48.4
Kendal's W test	0.431**	0.455**	0.443**	0.360**	0.430**	0.422**	0.238**	0.244**	

Table 3. Sensory scores of ginger candy after four months of storage

Genotypes	Appearance	Colour	Flavour	Texture	Odour	Taste	After taste	Overall acceptability	Total score
SE 86 26	5.87	7.00	6.73	7.00	6.85	7.00	6.85	6.73	54.03
SE 86 83	6.20	7.33	6.85	7.00	7.30	8.03	8.00	8.03	58.74
C 8626	8.00	6.85	7.00	7.27	8.03	8.05	8.00	8.00	61.20
CHP 118	6.20	4.90	5.15	4.90	4.25	4.90	7.80	7.95	46.05
C 78 284	6.35	5.30	5.55	4.65	5.30	4.60	5.30	5.80	42.85
SE 86 102	6.80	6.00	6.00	4.90	5.70	6.00	5.55	5.70	46.65
SE 86 42	7.30	7.30	7.10	8.00	7.10	8.00	7.55	6.85	59.20
C 86 32	6.35	5.35	5.15	5.05	4.75	5.15	5.05	7.30	44.15
CHP 99	6.45	5.35	5.35	5.53	5.65	7.00	7.00	6.20	48.53
CHP282	6.35	5.37	5.37	5.27	5.15	5.65	5.15	6.25	44.56
Aswathy	6.20	5.53	5.15	5.55	5.27	6.73	5.87	6.73	47.03
Kendal's W test	0.331**	0.415**	0.403**	0.390**	0.330**	0.412**	0.239**	0.245**	

Table 4. Sensory scores of ginger candy after six months of storage

Genotypes	Appearance	Colour	Flavour	Texture	Odour	Taste	After taste	Overall acceptability	Total score
SE 86 26	5.55	6.73	6.25	6.85	6.23	6.47	6.20	6.70	50.98
SE 86 83	6.00	7.00	6.73	6.6	7.00	8.00	7.95	7.03	56.31
C 8626	7.80	6.73	6.73	7.00	8.00	8.00	7.30	7.27	58.83
CHP 118	6.00	4.60	5.30	4.60	4.05	4.90	7.77	5.27	42.49
C 78 284	6.05	4.90	5.50	4.25	5.25	4.40	4.65	5.27	40.27
SE 86 102	6.73	5.87	5.65	4.60	5.27	5.73	5.27	5.27	44.39
SE 86 42	7.43	7.10	7.00	7.77	7.00	7.95	7.30	6.73	58.28
C 86 32	6.20	5.15	5.05	5.27	4.60	4.60	5.05	5.37	41.29
CHP 99	6.50	5.27	5.25	5.05	5.55	6.85	6.73	6.27	47.47
CHP282	6.25	5.25	5.27	5.05	4.40	5.25	505	5.53	542
Aswathy	6.00	5.27	5.25	5.15	5.15	6.25	5.55	6.47	45.09
Kendal's W test	0.391**	0.515**	0.303**	0.440**	0.450**	0.439**	0.430**	0.345**	

Table 5. Sensory scores of fresh ginger flakes

Genotypes	Appearance	Colour	Flavour	Texture	Odour	Taste	After taste	Overall acceptability	Total score
SE 86 26	6.05	7.30	7.00	7.27	7.00	7.55	7.30	7.03	56.50
SE 86 83	7.55	7.43	8.83	7.77	7.55	8.05	8.03	8.93	64.14
C 8626	8.05	7.00	7.33	7.55	8.05	8.15	8.05	7.62	61.80
CHP 118	6.25	5.05	5.35	5.35	4.60	5.05	5.80	6.45	43.90
C 78 284	6.40	5.30	5.75	4.48	5.37	4.65	5.37	6.25	43.57
SE 86 102	7.00	6.02	6.02	5.05	6.05	6.23	5.57	7.03	48.97
SE 86 42	7.43	7.55	7.33	8.83	7.77	8.05	7.77	8.53	63.26
C 86 32	6.40	5.53	5.53	5.37	5.15	5.37	5.27	6.32	44.94
CHP 99	6.47	5.82	5.55	5.70	6.00	7.93	7.80	6.47	51.74
CHP282	6.80	6.00	5.75	5.37	6.00	5.75	5.08	6.47	47.22
Aswathy	6.53	5.83	5.55	5.77	5.87	6.60	6.47	7.62	50.24
Kendal's W test	0.309**	0.425**	0.300**	0.330**	0.320**	0.329**	0.330**	0.325**	

Table 6. Sensory scores of ginger flakes after two months of storage

Genotypes	Appearance	Colour	Flavour	Texture	Odour	Taste	After taste	Overall acceptability	Total score
SE 86 26	6.00	7.27	6.80	7.10	6.8	7.27	7.00	7.10	55.34
SE 86 83	7.43	7.33	8.65	7.62	7.43	8.00	8.00	8.83	63.29
C 8626	8.03	6.73	7.25	7.45	8.00	8.00	8.00	7.55	61.01
CHP 118	6.02	4.90	5.25	5.30	4.48	4.75	5.75	6.32	42.77
C 78 284	6.33	5.27	5.65	4.75	5.27	4.60	5.27	6.02	43.16
SE 86 102	6.73	6.00	6.00	4.90	6.00	6.02	5.37	6.47	47.49
SE 86 42	7.30	7.43	7.30	8.65	7.45	8.00	7.70	7.95	61.78
C 86 32	6.32	5.47	5.47	5.27	5.05	5.27	5.05	6.02	43.92
CHP 99	6.45	5.75	5.47	5.55	5.82	7.80	7.70	6.45	50.99
CHP282	6.32	5.82	5.53	5.45	5.90	5.57	5.05	6.32	45.96
Aswathy	6.47	5.75	5.53	5.75	5.75	6.50	6.45	7.55	49.75
Kendal's W test	0.421**	0.515**	0.323**	0.410**	0.490**	0.429**	0.420**	0.341**	

Table 7. Sensory scores of ginger flakes after four months of storage

Genotypes	Appearance	Colour	Flavour	Texture	Odour	Taste	After taste	Overall acceptability	Total score
SE 86 26	5.70	7.10	6.70	7.00	6.70	7.10	6.80	7.00	54.10
SE 86 83	7.30	7.30	8.60	7.55	7.30	7.77	7.80	8.65	62.27
C 8626	8.00	6.70	7.10	7.30	7.93	7.90	7.90	7.33	60.16
CHP 118	6.00	4.75	5.08	5.08	4.40	4.65	5.65	6.27	41.88
C 78 284	6.30	5.15	5.55	4.65	5.15	4.48	5.05	6.00	42.33
SE 86 102	6.70	4.60	5.90	4.60	5.75	6.00	5.27	6.40	45.22
SE 86 42	7.27	7.33	7.10	8.60	7.30	7.90	7.55	7.80	60.85
C 86 32	6.30	5.45	5.45	5.15	4.65	5.05	4.75	6.00	42.80
CHP 99	6.35	5.70	5.40	5.45	5.82	7.62	7.62	6.33	50.29
CHP282	6.30	5.77	5.50	5.30	5.83	5.45	4.75	6.20	45.10
Aswathy	6.35	5.70	5.45	5.55	5.57	6.30	6.30	7.30	48.52
Kendal's W test	0.390**	0.519**	0.213**	0.401**	0.422**	0.433**	0.432**	0.347**	

Table 8 Sensory scores of ginger flakes after six months of storage

Genotypes	Appearance	Colour	Flavour	Texture	Odour	Taste	After taste	Overall acceptability	Total score
SE 86 26	5.53	7.00	6.60	6.80	6.70	7.00	6.70	5.53	51.86
SE 86 83	7.27	7.27	8.35	6.70	7.30	7.70	7.60	6.47	58.66
C 8626	7.90	6.47	7.01	7.00	7.77	7.70	7.80	6.47	58.12
CHP 118	5.93	4.48	5.08	5.05	4.20	4.60	5.55	5.27	40.16
C 78 284	6.20	5.05	5.55	4.60	5.05	4.65	4.75	5.27	41.12
SE 86 102	6.45	4.40	5.90	4.48	5.53	5.82	5.15	6.47	44.2
SE 86 42	7.10	7.27	7.10	8.33	7.10	7.80	7.45	6.25	58.4
C 86 32	6.00	5.30	5.45	5.08	4.60	4.90	4.65	5.37	41.35
CHP 99	6.33	5.65	5.40	5.40	5.77	7.27	7.30	5.53	48.65
CHP282	6.27	5.45	5.50	5.08	5.82	5.30	4.65	5.53	43.6
Aswathy	6.33	5.65	5.45	5.40	5.53	6.00	5.53	5.53	45.42
Kendal's W test	0.372**	0.453**	0.344**	0.453**	0.454**	0.422**	0.428**	0.325**	

Table 9.Sensory scores of fresh ginger powder

Genotypes	Appearance	Colour	Flavour	Texture	Odour	Taste	After taste	Overall acceptability	Total score
SE 86 26	7.43	7.55	7.00	6.00	7.00	6.00	7.30	7.93	56.21
SE 86 83	8.83	8.33	7.77	8.05	7.55	8.15	8.03	8.57	65.28
C 8626	7.33	7.00	7.55	7.33	7.27	8.15	8.05	8.45	61.13
CHP 118	6.25	5.05	5.37	5.35	4.75	5.05	5.87	6.25	43.94
C 78 284	6.40	5.30	5.75	4.48	5.37	4.65	5.37	8.45	45.77
SE 86 102	7.00	5.37	6.27	5.05	6.00	6.50	5.57	7.03	48.79
SE 86 42	7.77	7.55	7.45	8.83	7.55	8.03	8.05	8.53	63.76
C 86 32	7.43	8.05	7.55	7.30	7.30	8.83	7.77	8.53	62.76
CHP 99	6.73	5.90	5.47	5.87	5.87	7.43	7.55	6.47	51.29
CHP282	6.73	6.00	5.37	4.48	5.37	5.80	5.27	6.47	45.49
Aswathy	6.25	6.02	5.35	5.70	5.37	6.85	7.30	7.62	50.46
Kendal's W test	0.365**	0.235**	0.313**	0.435**	0.452**	0.431**	0.421**	0.343**	

Table 10. Sensory scores of ginger powder after two months of storage

Genotypes	Appearance	Colour	Flavour	Texture	Odour	Taste	After taste	Overall acceptability	Total score
SE 86 26	7.30	7.45	6.73	5.83	6.70	5.83	5.93	7.77	53.54
SE 86 83	7.90	8.15	7.27	8.00	7.45	8.15	8.03	8.35	63.30
C 8626	7.27	6.80	7.27	7.30	7.80	8.00	8.00	8.33	60.77
CHP 118	6.47	4.65	5.35	5.30	4.48	4.90	5.55	6.06	42.76
C 78 284	6.06	4.90	5.55	4.40	5.25	4.65	5.25	8.35	44.41
SE 86 102	6.70	5.27	6.20	4.90	5.85	6.47	5.47	7.00	47.86
SE 86 42	7.43	7.45	7.43	8.70	7.45	8.00	7.90	8.35	62.71
C 86 32	7.33	8.00	7.45	7.10	7.00	8.70	7.70	8.35	61.63
CHP 99	6.20	5.85	5.40	5.65	5.85	7.33	7.45	6.40	50.13
CHP282	6.70	5.05	5.30	4.40	5.30	5.75	5.08	6.45	44.03
Aswathy	6.20	6.00	5.30	5.47	5.30	6.73	7.10	7.60	49.70
Kendal's W test	0.392**	0.534**	0.313**	0.442**	0.452**	0.437**	0.431**	0.371**	

Table 11. Sensory scores of ginger powder after four months of storage

Genotypes	Appearance	Colour	Flavour	Texture	Odour	Taste	After taste	Overall acceptability	Total score
SE 86 26	7.27	7.30	6.50	5.75	6.60	5.75	5.82	7.70	52.69
SE 86 83	6.23	7.43	7.00	7.77	7.30	8.05	8.00	8.15	59.93
C 8626	7.10	6.73	7.10	7.10	7.70	7.90	7.77	8.17	59.57
CHP 118	6.40	4.48	5.25	5.27	4.40	4.60	4.90	8.10	43.40
C 78 284	6.00	4.60	5.75	4.40	5.15	4.60	5.15	7.60	43.25
SE 86 102	5.55	5.15	6.00	4.60	5.70	6.23	5.47	7.00	45.70
SE 86 42	7.33	7.30	7.33	8.15	7.30	8.00	7.77	8.33	61.51
C 86 32	6.40	7.77	6.73	6.80	6.70	7.55	7.70	8.33	57.98
CHP 99	6.02	5.82	5.40	5.55	5.77	7.27	7.45	6.33	49.61
CHP282	6.70	4.90	5.27	4.20	5.27	5.73	5.05	6.40	43.52
Aswathy	6.20	5.87	5.15	5.55	5.05	6.70	6.70	7.45	48.67
Kendal's W test	0.491**	0.532**	0.363**	0.445**	0.452**	0.419**	0.418**	0.328**	

Table 12. Sensory scores of ginger powder after four months of storage

Genotypes	Appearance	Colour	Flavour	Texture	Odour	Taste	After taste	Overall acceptability	Total score
SE 86 26	7.27	7.00	6.47	5.70	6.53	5.57	5.77	7.27	51.58
SE 86 83	6.00	7.30	7.00	7.27	7.10	8.00	8.00	7.77	58.44
C 8626	7.00	6.32	7.00	7.00	7.45	7.80	7.45	8.00	58.02
CHP 118	6.25	4.40	5.27	5.27	4.20	4.48	4.60	7.27	41.74
C 78 284	6.4	4.40	5.15	4.40	5.08	4.60	5.08	7.45	42.56
SE 86 102	5.82	4.48	4.75	4.60	5.37	6.23	5.45	6.73	43.43
SE 86 42	7.30	7.00	6.47	6.32	7.30	8.00	7.45	8.33	58.17
C 86 32	6.40	5.53	7.30	8.00	5.15	6.73	7.00	6.27	52.38
CHP 99	6.00	5.53	5.40	5.30	5.08	7.27	7.30	5.47	47.35
CHP282	6.70	4.60	5.27	4.00	5.27	5.05	4.90	5.53	41.32
Aswathy	6.02	5.55	5.08	5.45	4.75	6.60	6.20	6.80	46.45
Kendal's W test	0.027**	0.345**	0.317**	0.243**	0.456**	0.431**	0.422**	0.324**	

SCREENING GINGER (*Zingiber officinale* Rosc.) GENOTYPES UNDER DIFFERENT GROWING CONDITIONS AND FOR VALUE ADDITION

by
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(2015-22-003)

ABSTRACT

Submitted in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY IN HORTICULTURE

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2018

ABSTRACT

Ginger is an important commercial spice crop grown in India for culinary and medicinal purposes. The present study entitled "Screening ginger (*Zingiber officinale* Rosc.) genotypes under different growing conditions and for value addition" was taken up at College of Horticulture, Vellanikkara during 2015-18 to evaluate the performance of ginger genotypes with respect to yield and quality, growth under different growing conditions, quality of different maturity stages and to identify types suitable for different value added products. A total of fourteen somaclones developed through indirect organogenesis and indirect embryogenesis were selected for the study.

Genotypes exhibited wide variability in plant characters, yield characters and quality attributes. Plant height was maximum in the somaclone SE 86102 (107.35 cm) at 6 months growth stage. Number of tillers was maximum in CHP118 (20.33) at 6 months stage. Number of leaves per shoot was found higher in CHP 118 (28.67) and in SE 86 26. Leaf area was the highest in CHP 118 at 4 months stage and C8632 at 6 months stage. Among the physiological parameters recorded, photosynthetic and transpiration rates were the highest in CHP 118 and SE 86 42. Number of primary and secondary rhizomes was maximum in SE 8626, CHP 118 and C8632 (>30 t/ha). Weight of primary and secondary rhizomes was highest in SE 8626 and SE 8642. Fresh yield was highest in SE 8626, CHP 118, SE 8642 & C 8632. Driage (23%) and dry yield (7.9t/ha) were the highest in SE 8626. The quality attributes such as volatile oil, oleoresin and crude fiber contents varied significantly among the genotypes. The highest content of volatile oil (3.62%) was recorded in CHP 118. Oleoresin content (>6%) was maximum in Rio-de- Jenairo. Fibre content increased with age of rhizomes recording lowest values (< 2.5%) in SE 86 83, C 86 26 and SE 86 42. Highest content of Gingerol (1.48 %) and Shogoal (0.16%) was recorded in Rio –de- Janeiro and CHP 282 respectively.

Among the genotypes evaluated under different growing conditions, variability in plant height was observed. During the growth stages, all the genotypes exhibited higher plant height under rain shelter condition, whereas at 6 months stage plants were taller in open field. Number of tillers and leaves were significantly higher in open condition. Tiller number ranged from 14 to 17 under open field and 6 to 7 in rain shelter. Leaf area was the highest at 5 months growth stage which later decreased. Among the two growing conditions, the highest leaf area was observed in open condition in SE 8640 and SEHP 9. Generally, somaclones grown in open condition recorded higher yield and SEHP 9, SE 8081 and SE 8640 were identified as higher yielders. But in SE 86 40, the yield was on par both in open and rain shelter conditions indicating its suitability for growing under rain shelter condition. Driage did not differ significantly between the two growing conditions. Driage and dry yield were higher in SE 86 81 and SEHP 9. Higher values for photosynthetic rate, transpiration rate and stomatal conductance were recorded in open field.

Among the two growing conditions, quality parameters were higher in rainshelter cultivation though not significant. SE 8640 recorded the highest volatile oil content under both growing conditions (open field -4.45 % and rain shelter -4.67 %). All genotypes except SE 8640 recorded an oleoresin content of more than 5 %. Fibre content increased with maturity recording maximum values at 7 months stage. Lower fibre content was recorded under rain shelter condition. Among the somaclones, SE 8681 and SE 86131 recorded lower values for fiber content at 5 months stage.

Elite varieties satisfying the requirements for specific end products are the need of the hour to capitalize on the processing front. Biochemical parameters such as moisture content, TSS, titratable acidity, pH and colour were recorded for analyzing the storage stability of the products *viz.,* candy, flakes and powder. The somaclones SE 8683, C 8626 and SE 8642 were found to be the best for candy preparation based on its overall consumer acceptability and storage stability. SE

8683, C 8626 and SE 8642 were found suitable for flakes preparation and SE 8683, C 8626, SE 8642 and C8632 for making quality ginger powder.