SURVEY, CHARACTERIZATION AND EVALUATION OF CLOVE (*Syzigium aromaticum* (L) Merr. & Perry) ACCESSIONS

by

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(2016-12-023)

THESIS

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DECLARATION

I, hereby declare that this thesis, entitled **"SURVEY, CHARACTERIZATION AND EVALUATION OF CLOVE (*Syzigium aromaticum* (L) Merr. & Perry) ACCESSIONS"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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Avinash M.

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LIST OF ABBREVIATIONS

%	Per cent
°C	Degree Celsius
ANOVA	Analysis of variance
ASTA	American Spice Trade Association
CD	Critical difference
Cm	Centimeter
cm^2	Square centimeter
et al.	And others
FAO	Food and Agriculture Organization
Fig.	Figure
g	Gram
GC	Gas chromatography
ID	Identity document
i.e.	That is
IPGRI	International Plant Genetic Resources Institute
K	Potassium
KAU	Kerala Agricultural University
Kg	Kilogram
M	Metre
m^2	Square metre
MDS	Minimum data set
mg	Milligram
mm	Milli meter
MS	Mass spectroscopy
MSL	Mean Sea Level

N	Nitrogen
NBPGR	National Bureau of Plant Genetic Resources
NIST	National Institute of Standard and Technology
NS	Non Significant
No.	Number
P	Phosphorus
PPVFRA	Protection of Plant Varieties and Farmers Right Authority
PCA	Principal Component Analysis
pH	Potenz hydrogen
Spp.	Species
Var.	Variety
vs	Versus
Viz.,	Namely

INTRODUCTION

1. INTRODUCTION

Clove of commerce, the dried unopened flower buds of an evergreen tree, *Syzygium aromaticum* (L.) Merr. & Perry of family Myrtaceae is a highly preferred spice. Native to Moluccas island of Indonesia, it is one of the most ancient and valuable spices cultivated mainly in countries like Indonesia, Zanzibar, Madagascar, Pemba and Sri Lanka. The world production of clove is estimated to be 1,80,520 tonnes (FAO, 2016) with Indonesia accounting for 77 per cent of world production. Europe and India are the major importers of high quality cloves (FAO, 2013) and clove production in India is only 1,000 tonnes per annum (NHB, 2013).

Clove provides spicy aroma and is used as a culinary spice either in whole or in ground form. It is used as a staple ingredient in most curried dishes (Teuscher *et al.*, 2005) and is widely used in dentistry, cosmetics and perfumery. But majority of world production goes into the manufacture of 'kretek' cigarettes in Indonesia. Clove oil is rich in eugenol.

In India, though clove has been under cultivation for over 150 years, the production in the country is not sufficient to meet the internal demand. The demand for clove is going to be steady in the years to come due to relatively less cost of production, low incidence of pests and diseases, better price, assured market and perennial source of income except for the stringency of workers during picking time (Sasikumar *et al.*, 2016).

Clove was first introduced in India around 1800 AD by the East India Company in their "spice garden" in Courtallam, Tamil Nadu. Variability in clove in India is limited and the present day population in India originated from a few trees with narrow genetic base originally introduced into India. Moreover, the self-pollinating nature also limited the scope for variability. In India, the major clove growing regions are Kanyakumari, Nilgiris and Namakkal of Tamil Nadu, Calicut, Kottayam, Quilon and Trivandrum districts of Kerala and South Kanara of Karnataka (Balakrishnamoorthy and Kennedy, 1999). At present, the crop

improvement programme in clove is limited to selection of mother trees based on regular and heavy bearing nature by surveying major clove growing areas. The major breeding objective of clove is to develop high yielding, dwarf and bold cloves due to the low availability of labour. But, due to the lack of variability, it is difficult to achieve these aims. Hence, only local types were under cultivation and no true variety of clove was recognized in India due to lack of characterization and evaluation studies. Thus, there is a need to identify variability in clove plants from the major clove growing areas and to develop qualitative and quantitative characterization.

It was in this background the present study entitled "Survey, characterization and evaluation of clove (*Syzigium aromaticum* (L) Merr. & Perry) accessions" was taken up exclusively with the specific objective to characterize clove accessions based on morphological and biochemical parameters. Hence this will become the first step to visualise and conceptualise the association of visible and invisible traits in clove to develop an ideotype.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Clove, botanically *Syzygium aromaticum* (L.) Merr & Perry. belonging to the family Myrtaceae is a native of Moluccas Island of Indonesia where it occurs as a second storey forest tree on the lower mountain slope. The clove of commerce is dried, aromatic, fully grown unopened flower bud. In India, clove cultivation is limited to parts of Tamil Nadu, Kerala, Karnataka and Andaman and Nicobar Islands. The world production of clove is estimated to be 1,37,398 tonnes (FAO, 2013) and the imports of cloves into India more than doubled in last five years with an annual demand ranging between 15,000 to 20,000 tonnes. The constraints in clove cultivation are long prebearing period, lack of proper scientific culture, crop management, lack of availability of reliable planting material, difficulty in harvesting the produce, since 30 to 35 per cent of crop loss occurs due to inaccessible height of the plant. Hence there is a need to produce, short statured high yielding clove types. Considering the increasing demand of clove and the need of the farmer, it is necessary to identify a suitable ideotype in clove. Research work in clove is meager in India. Hence an effort has been initiated on survey, characterization and evaluation of clove accessions in the major clove growing regions of southern Kerala and Kanyakumari. In this chapter, the relevant literature on morphological and biochemical studies on clove is presented under various subtitles. Wherever literature on clove was limited, relevant research works on other perennial trees and tree spices were also presented.

2.1 Survey and collection of clove and related tree species

Myrataceae family has about 45 genera and 3000 species of trees and shrubs. The genus *Syzygium* has about 500 species in the world. Many species of *Syzygium* occur in Indian sub-continent, but they were all very distant species resembling clove only on taxanomic basis, some of the important species occurring in India included *Syzygium aromaticum* (cultivated clove), *S. cuminii*, *S. fruiticosum, S. zeylanicum. S. jambos, S travancoricum, and S. jambolana* (Peter

and Abraham, 2007). Recently Brambach *et al.* (2017) identified 5 new species of *Syzygium* from Indonesia and much diversity was seen among the species. The five-species proposed as new were *Syzygium balgooyi* sp. nov., *Syzygium contiguum* sp. nov., *Syzygium devogelii* sp. nov., *Syzygium eymae* sp. nov., and *Syzygium galanthum* sp. nov.

Pool *et al.* (1986) surveyed one hundred clove trees of 34 wild and cultivated populations in the north and central Moluccas. There was considerable variation among wild clove trees than cultivated types. Good morphological variation in several cultivated populations especially in terms of flower bud, leaf and flower bud clusters characters were reported.

Krishnamoorthy and Rema (1992) surveyed the major clove-growing areas in Kanyakumari, Nilgiris and Salem district of Tamil Nadu and Quilon and Trivandrum district of Kerala to select high yielding elite clove trees for seed collection. They identified a total of 35 elite clove trees from three private estates which were located in the Ashamboo hills, the southern most hills containing the oldest clove trees in India. Three distinctly different morphological variants in cloves were located during the surveys conducted at Tamil Nadu. One king clove type, two dwarf and bushy clove type trees at Black Rock Estate and three small leaved clove trees from Maramalai Estate were located. The identified promising variants offered great potential for utilizing the diversity for crop improvement programmes.

In a survey conducted at Keeriparai and Maramalai regions of Kanyakumari by Balakrishnamoorthy and Kennedy (1999), two king clove types (KC-1 and KC-2) and one dwarf clove (DC-1) were reported based on morphological and flower bud characters and collected variants were evaluated at Horticulture Research Station, Yercaud.

Balakrishnamoorthy and Kennedy (1999) also identified 12 high yielding types based on five years performance from the private estates of Nagercoil and

mother cloves of this types were collected and evaluated at Horticulture Research Station, Yercaud.

A survey was undertaken by Miniraj *et al.* (2015) in the nutmeg growing regions of Kerala and collected few accessions. Morphological and biochemical characterization of these collected accessions revealed monoecious types, unique types with yellow mace and other superior types with excellent nut and mace characters. Collected accessions were maintained in nutmeg germplasm centre at Kerala Agricultural University, Thrissur.

2.2 Morphological characterization of clove and related tree species

In India, the genetic base of clove is narrow hence variability in clove is very limited. The origin of present-day clove populations were from very limited trees introduced to our country (Nybe *et al.*, 2006). Besides this, self-pollinating nature of the crop also led to lack of variability. In India generally, local types were under cultivation and no true variety of clove was recognized.

2.2.1 Tree characteristics

The clove tree is small to medium evergreen tree which grows to a height of 12 to15 m, conical in shape when young, later becoming roughly cylindrical (Purseglove *et al.*, 1981). The tree is myrtle which begins to flowering in about 7 years and continues to produce yield for 80 or more years (Pruthi, 2001).

Krishnamoorthy and Rema (1994a) reported two 16 year old clove trees at Black Rock Estate, Kanyakumari which were dwarf, bushy and 2 m tall with a canopy width of 5 m, the main trunk was only 0.6 m in height with profuse branches. Seedling raised from these trees exhibits dwarf nature, based on preliminary observations. This promising accession was registered with NBPGR, New Delhi for its dwarf stature with accession number INGR-04112.

In India, differences have been recorded in the shape of trees, bearing habits, cropping season and also variation in yield, colour, shape and dimension of clove (NIIR, 2006).

In clove, Pool *et al.* (1986) recorded three types of canopy conformation i.e. round, pyramidical and cylindrical. Clove trunk is composed of hardwood. Some time it forks near the base of the tree into two to three main erect branches (Purseglove *et al.*, 1981). Tree girth is an important morphological character for assessing the productivity in clove (Balakrishnan *et al.*, 1998) and it could be measured at 45 cm height from the base of the tree (Kennedy and Nageswari, 2000).

Joy *et al.* 1998 reported significant variability in tree canopy shape of cinnamon and concluded that spherical shape was predominant followed by semi spherical and linear shape. In nutmeg, four different forms of tree canopy shapes *viz.* conical, pyramidical, oblong and globular was reported by Vikram (2016) and the pyramidical shape was the most common. Narrowly pyramidal shape tree in nutmeg can be utilized in high density planting system (Priyanka and Miniraj, 2016). Erect and spreading were two types of branching pattern were recorded in nutmeg (Vikram, 2016).

Brinkgreive (1933) recorded that farmers in West Sumatra recognized differences in branching conformation (pattern) in clove.

2.2.2 Leaf characteristics

Clove leaves are simple, opposite, coriaceous, exstipulate, glabrous and aromatic. The petiole is slender and about 2 to 3 cm long, swollen and pinkish at the base showing 7 to 13 cm length and 3 cm width. The shape of the leaf apex is shortly or broadly bluntly and acuminate. New leaves appeared in the flushes were bright pink in colour and mature leaves were dark green (Purseglove *et al.*, 1981). The leaves were obovate, oblong to elliptic, opposite and possess plenty of oil glands on the lower surface (Ravindran *et al.*, 2006). Balakrishna *et al.* (1998) reported that measurement of leaf area was one of the important method of

assessing the variability and productivity. Twenty four clove accessions maintained at Horticulture Research Station, Pechiparai revealed that the accession SA-3 recorded the highest leaf length of 16.5 cm and leaf breadth 6.2 cm (AICRP, 2015).

In nutmeg, Vikram (2016) found significant variability in the colour of flushes, colour of mature leaf, leaf shape and leaf apex shape. Colour of the flushes reported were yellowish green, greenish yellow and light green colour. Five different types of mature leaf shape were recorded, and predominant shape noted was elliptic followed by lanceolate, obovate, ovate and oblong. With regard to the mature leaf colour, green, dark green and light green were reported. The most common leaf apex shape in nutmeg were acuminate and acute shape and rarely obtuse leaf apex was also noticed.

Investigation on the genetic variability among 234 accessions of cinnamon maintained at the Aromatic and Medicinal Plants Research Station, Odakali revealed that 14% has deep flushes, 72% medium coloured flushes and 14% light coloured or green flushes. Similarly, the leaves size was small to medium in 46%, medium to large in 22%, and small to large in 32% of the accessions evaluated (Joy *et al.*, 1998). Based on the varied type of leaf size and colour, Sahoo *et al.* (1998) has grouped the leaves as small ovate light green, large ovate light green, medium narrow dark green, long narrow dark green etc. Leaves were simple, alternate or sub-opposite, oblong ovate or narrowly elliptic in cinnamon.

2.2.3 Bud, flower, fruit and seed characteristics

The inflorescence is a terminal, trichotomous panicle, corymbose, shortly pedunculate and branched from the base and was highly variable in the number of flowers. It varies from 3 to 20 flowers per panicle (Purseglove *et al.*, 1981 and Ravindran *et al.*, 2006). The flowers were produced at the terminal end of the four to five cm long clusters. Botanically they are paniculate cymes and consisted of three to ten groups of three flowers each. The extent of the branching of the stalk of the inflorescences showed the actual crop yield in clove (Wit, 1969).

The flower is hermaphrodite and consists of a fleshy hypanthium which is surmounted by four fleshy sepals. The hypanthium is 1 to 1.5 cm long and diameter of 5 mm, angled, cylindrical and base slightly narrowed. Color of the hypanthium is green in the young bud, flushed pink at anthesis and turns deep reddish after the fallen of stamens. The four fleshy calyx are triangular, slightly incurved and 3 to 4 mm long. The four petals are imbricate, red tinged, rounded, 6 mm diameter and looks like a hemispherical calyptra. The style is very stout, swollen at the base, pale green and 3 to 4 mm long. Top of the hypanthium enclose two-celled ovary (Purseglove *et al.*, 1981).

Krishnamoorthy and Rema (1992) reported that age, number of flower buds per inflorescence, number of inflorescences per branch and size of the flower bud determines the yield in clove.

According to the Joshy (1946) inflorescence produced in the nutmeg are axillary raceme. But it is a branched inflorescence in male tree and simple cyme in female trees (Joseph, 1980). Flowers were drooping, creamy yellow and fragrant. (Krishnamoorthy, 2000).

In *Cinnamomum sulphuratum,* flowers are hermaphrodite, axillary panicles and mean number of flowers per inflorescence reported was 62.48±7.01. Flowers have greenish white coloured peduncles (Shivaprasad *et al.*, 2015).

Clove fruit is single seeded drupe and popularly known as mother of clove. The color of the fruit is reddish purple, 2.5 to 3.5 cm long and 1.2 to 1.5 cm in diameter. It is usually tapering at each end and surmounted by the four enlarged fleshy calyx lobes. Fruit contains fleshy pericarp about 2 to 3 mm thick (Purseglove *et al.*, 1981). The seed is oblong in shape and rounded at both ends, about 2 cm long, purplish color testa, with two large cotyledons and no endosperm. Ravindran *et al.* (2006) reported that clove fruit contains one oblong shaped fruit of about 1.5 cm length. Seed characters of progenies of 14 elite clove trees revealed no appreciable variation for 100 fruit weight, 100 seed weight, fruit breadth, fruit length, seed breadth and seed length (Krishnamoorthy and Rema, 1994b).

Round, oval, ovoid and pyriform are four different forms of fruit shape in nutmeg (Vikram, 2016). Priyanka and Miniraj (2016) observed oblong shaped fruit in nutmeg. Purseglove *et al.* (1981) described the seeds as a round or oval shape with brown testa. A good amount of variability has been reported in growth rate, productivity, size and shape of the leaf, flower size and shape, fruit set and size of the fruit and seed in nutmeg (Krishnamoorthy *et al.*, 1996; Haldankar *et al.*, 2004; Haldankar *et al.*, 2006; Sasikumar, 2009).

Ashraf (1987) reported that fruit shape in jamun varied from round to oblong and apex of fruits from flat to pointed one.

Hareesh and Vasudeva (2010) worked on variation for fruit and seed traits of *Garcinia indica* Choisy and observed variation for fruit colour, shape and taste. They identified eight variants which vary in terms of colour, shape and taste of fruits.

Different fruit morphotypes like red type, orange, green and yellow types were identified by Nivedita (2013) in *Garcinia indica* Choisy. Based on fruit apex shape, projected, flat and sunken type and based on fruit base shape, round and flattened were described. Shape of the fruit found included round and pear shape.

2.3 Variability in clove and related tree species

Morphological characteristics, yield and yield attributing traits were evaluated to identify promising clove accessions at Pechiparai. Among the 14 accessions, SA-13 recorded the highest yield of 9.08 kg buds per tree and from the pooled mean of three years yield and SA-l, SA-3, SA-l2 and SA 13 were identified as promising accessions (AICRP 2007).

A study was conducted to determine the genetic diversity among twenty eight clove accession planted in the Experimental Garden Sukapura, East Java. Out of fifteen morphological characters and six yield components characters, eleven characters had wide genetic diversity. Characters like wet weight per kg of flowers,

fruit and the stalk, the diameter of the tube top, length of the branch and the number of branches showed important role in diversity studies in cloves (Tresniawati and Randriani, 2011).

In a study on genetic variability of nutmeg, progenies from 16 mother trees of different localities (five progenies for each mother tree) showed significant differences among the populations for plant height, number of main shoots, number of years for flowering, fruit weight and ratio of mace weight to seed weight. The phenotypic coefficient of variation was more than the genotypic coefficient of variation, indicating the role of environment in the expression of these characters (Krishnamoorthy *et al.*, 1996).

Mathew *et al.* (1999) identified two seedling variants in all spice that showed distinct morphological variation with respect to height, canopy shape, branching habit, internodal length, leaf characters and plant height. The variants were multiplied clonally and all the clones exhibited the parental character.

Ponnuswamy *et al.* (1982) recorded high co-efficient of variability for number of peeler shoots per plant, plant height, plant girth and tree spread after evaluating 101 open pollinated accessions of cinnamon. Krishnamoorthy *et al.* (1991) reported significant variation in progeny performance of nine lines for plant height, number of branches per tree, fresh and dry weight of bark and percentage recovery of bark in cinnamon. In the field plantation of cinnamon in Orissa, Paul and Sahoo (1993) reported wide variations in plant height (2.17-3.37m), stem girth (7-16.6cm), leaf oil (0.38-1.80%), eugenol in leaf oil (traces to 80-98%) and bark oil (0.05-2.18%).

Fifteen accessions of *C. zeylanicum* which were collected from Western Ghats of southern India revealed 89% of polymorphism with 11 RAPD primers. Jaccard's similarity matrix revealed that, the level of genetic similarity between accessions ranged from 0.33 to 0.87. Dendrogram revealed the formation of 5 major genetic groups among 15 accessions studied. The significant degree of variation

(low similarity Index 0.33) between the accessions CZ-440 and CZ-456 revealed maximum genetic diversity. There was a close genetic similarity between accessions CZ-456 and CZ-452 (Sandigawad *et al.*, 2011).

Abraham *et al.* (2006) collected and characterized fifty-six accessions of Malabar tamarind from Western Ghats regions of Karnataka and Kerala. Accessions exhibited maximum variability for fruit colour, fruit shape, fruit size, nature of branching, canopy shape, fruit weight, fruit girth, rind weight and rind thickness. Characterization of 13 fruit and 5 seed characters done for 51 accessions revealed maximum variability for fruit nipple length (74.8%) and minimum for fruit girth (12.8%).

Lalitha *et al.* (1997) reported large amount of variability with respect to plant height, leaf length, leaflet length, main stem thickness, number of branches per plant, oil content and composition of essential oil in curry leaf.

2.4 Biochemical characterization of clove

The characteristic odour and flavour properties of the clove buds, stems and leaves are mainly due to the composition of aromatic volatile oils. The major essential oils commercially extracted from clove tree are bud, stem and leaf essential oil (Alma *et al.*, 2007).

2.4.1 Clove bud oil

Clove bud oil is superior in odour and flavour compared to the other types of clove oil. The yield and organoleptic properties of the clove bud oil are dependent on the place of its origin and quality of clove. It also depends on method of preparation for distillation (Whole or grounded buds) and type of distillation procedure followed (Water or steam distillation). Clove bud oil is a colourless or yellow liquid which is obtained in a yield of 15 to 17 per cent on distillation. On water distillation it provides the finest oils for flavour and perfumery. Distillation of good quality clove yields 17 per cent essential oil (Purseglove *et al.*, 1981).

Ravindran *et al.* (2006) reported that the dried clove buds yield 14 to 21 percent essential oil.

2.4.2 Clove stem oil

Clove stem oil is extracted from the dried peduncles or stems of the clove buds. On distillation, it yields 6 per cent with a pale yellow coloured liquid which possesses a coarser and woody odour than bud oil. Stem oil has high eugenol content than bud oil. It is inferior in quality and many of them are using in the adulteration of the expensive bud oil (Purseglove *et al.*, 1981). Clove stems yield 4 to 5 per cent essential oil. Few substances which occur only in traces explains the coarser or woody odour of the stem oil. Also clove stem oil contains a few constituents which have not yet been observed in the clove bud oil (Pruthi, 2001).

2.4.3 Clove leaf oil

The clove leaf oil is a dark brown liquid and yields 2 to 3 per cent volatile oil with harsh and woody odour (Purseglove *et al.*, 1981). Pruthi (2001) reported that the yield of clove leaf oil ranged from 1 to 2 per cent.

2.4.4 Clove oleoresin

Clove bud oleoresin may be extracted from the dried clove buds and stems by using variety of organic solvents. It contains the volatile oil, the fatty oil and a number of other constituents which are soluble in particular solvent used. The recovery of oleoresin is of 18 to 22 per cent with benzene solvent, and 23 to 32 per cent with alcohol. Alcohol extracted oleoresin has a high resin content and it is unsuitable for perfumery purposes (Naves, 1974). The odour and flavour of clove oleoresin is considered superior than that of distilled oil like natural spices.

2.4.5 Eugenol content in clove

In clove, the major component of the commercially important essential oil is the phenol eugenol; and its per cent composition varies from one location to other.

Many researchers reported variation in eugenol composition from clove bud oil and it differed from 59.83, 89.20, 76.80, 70.00, 82.60, 87.00, 58.20, 47.60, 78.30 to 81.13 per cent (Porta *et al.,* 1998; Lee *et al.*, 2001; Jirovetz *et al.*, 2002; Srivastava *et al.*, 2005; Tomaino *et al.,* 2005; Alma *et al.,* 2007; Guan *et al.,* 2007; Memmou *et al.*, 2012; Nurdjannah, 2012 and Sohilait, 2015 respectively).

2.4.6 Profiling of clove volatiles

Alma *et al.* (2007) extracted the volatile oil from clove buds which were collected from Turkish company and subjected to GC-MS analysis. The investigated essential oils mainly had eugenol content 87% followed by eugenyl acetate 8.01% and β-caryophyllene 3.56%.

Biochemical profiling of clove essential oil which were extracted from clove buds collected from three different regions of India revealed main components of clove oil as eugenol which ranged from 78.5 to 87.7 per cent and caryophyllene 12.3 to 20.2 per cent (Priya *et al.*, 2015).

A comparative study of clove bud oil constituents collected from Java and Manado revealed significant differences between clove oil. Both origins had same major constituents but differ in percentage compositions. Chemo profiles of Java clove oil constituted majorly eugenol (55.60 %), eugenyl acetate (20.54 %), caryophyllene (14.84 %) and α-humulene (2.75 %). Manado clove was also rich in eugenol (74.64 %), eugenyl acetate (8.70 %), caryophyllene (12.79 %), and α-humulene (1.53 %). These results indicated that the geographic origin of the populations and the growing conditions may affect the chemical constituents in clove (Amelia *et al.*, 2017).

GC-MS analysis for clove bud oil from Toli-Toli and Bali in East Java revealed that the major compounds of clove oil were eugenol (66.37 % and 72.34 % respectively), caryophyllene (15.38 % and 12.51 % respectively), α-humulene (1.97 % and 2.34 % respectively) and eugenyl acetate (12.99 % and 5.33 % respectively). In Toli-Toli few unique minor compounds identified *viz.* β-

caryophylladienol (0.19 %) (+) and -δ-cadinene (0.13 %). Alloaromadendrene (0.24 %), δ-selinene (0.22 %) valencene (0.17 %) were the three compounds identified in Bali (Sulistyoningrum *et al.*, 2017).

Gas chromatography-mass spectrometry profiling of cinnamon volatiles showed cinnamaldehyde as predominant constituent (Kamaliroosta *et al.*, 2012).

Gas chromatography and mass spectrometry analysis of volatile oil of the nutmeg showed the presence of 38 components representing about 99.60 per cent of the total weight. Sabinene (29.40%) was found to be a major component followed by beta-pinene (10.60%), alpha pinene (10.10%), terpene-4-ol (9.60%) and several other minor components (Kapoor *et al.*, 2013).

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The study entitled "Survey, characterization and evaluation of clove (*Syzigium aromaticum* (L) Merr. & Perry) accessions" was carried out at clove plantations at Trivandrum, Kollam and Pathanamthitta district of Kerala and Kanyakumari district of Tamil Nadu during the period from January 2017 to April 2018.

3.1. SURVEY

The study was conducted in seven different locations after surveying of fifteen estates/location situated at major clove growing belts of Trivandrum, Kollam and Pathanamthitta district of Kerala and Kanyakumari district of Tamil Nadu which are the parts of Southern Western Ghats.

Survey was carried out to identify clove accessions showing morphological variability, diverse origin, superior yield and unique characters. After surveying 1610 plants, twenty accessions which showed special characters were selected for characterization and evaluation. Survey details like location, village, taluk, district, latitude, longitude, altitude, age of plant, habitat, ethnobotanical information, pest and diseases (resistance/ susceptibility/tolerance), special characters if any, manuring, fertilizer application, irrigation and pesticide application of the selected accessions were recorded.

3.1.1 Soil analysis

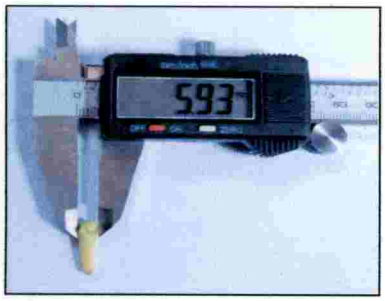
Soil samples were collected from 1.8 to 2 m away from the base of the selected trees at a depth of 30 cm. The collected samples were quartered and air dried. The air-dried soil samples were ground and passed through 2 mm sieve and stored in polythene bags for analysis. Samples were analyzed for major nutrients like N, P, K, organic carbon and soil pH. Based on soil test data, required nutrients were supplemented as per package of practices recommended by Kerala

Table 1. Selected clove accessions and their location details

Sl. no.	Accession ID	Location
1	BRC-1	Braemore Estate, Braemore, Thiruvananthapuram
2	BRC-2	Braemore Estate, Braemore, Thiruvananthapuram
3	BRC-3	Braemore Estate, Braemore, Thiruvananthapuram
4	BRC-4	Braemore Estate, Braemore, Thiruvananthapuram
5	MRC-5	Merchiston Estate, Ponmudi, Thiruvananthapuram
6	MRC-6	Merchiston Estate, Ponmudi, Thiruvananthapuram
7	MRC-7	Merchiston Estate, Ponmudi, Thiruvananthapuram
8	MRC-8	Merchiston Estate, Ponmudi, Thiruvananthapuram
9	AMC-9	Ambanad Estate, Aryankavu, Kollam
10	AMC-10	Ambanad Estate, Aryankavu, Kollam
11	AMC-11	Ambanad Estate, Aryankavu, Kollam
12	AMC-12	Ambanad Estate, Aryankavu, Kollam
13	AMC-13	Ambanad Estate, Aryankavu, Kollam
14	MMC-14	Alagappa Estate, Surlacode, Kanyakumari
15	MMC-15	Alagappa Estate, Surlacode, Kanyakumari
16	BLC-16	Pasukadai Estate, Gnalam, Kanyakumari
17	BLC-17	Pasukadai Estate, Gnalam, Kanyakumari
18	BLC-18	Pasukadai Estate, Gnalam, Kanyakumari
19	MGC-19	Marigold Estate, Brimore road, Nedumangad
20	ANC-20	District Agricultural Farm, Anchal, Kollam

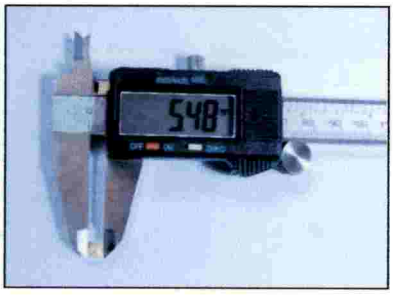
Merchiston Estate, Ponmudi

Plate 1. Study location and planters with the researcher

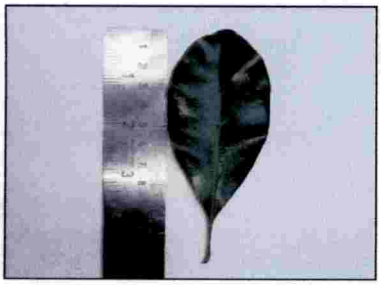


Breadth of flower head

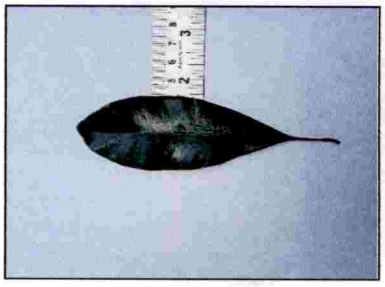
Length of flower



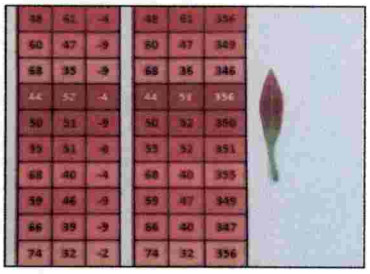
Breadth of petal



Length of leaf



Breadth of leaf



RHS Color chart

Plate 2. Measurement of flower and leaf characters in clove

Agricultural University (KAU, 2016). Fertilizer was placed in a circle closer to the tree base (canopy edge) for trees growing on level positions and upslope position of the tree for trees growing on sloped landscapes (Purbopuspito and Ree, 2002).

Table 2. Details of method used for soil analysis

Parameter	Method of estimation	Reference
Nitrogen	Alkaline permanganate method	Subbaiah and Asija (1956)
Phosphorus	Bray No. 1 extraction and spectrophotometer	Jackson (1973)
Potassium	Neutral Normal Ammonium Acetate extraction and flame photometry	Pratt (1965)
Organic carbon	Walkley and Black's Rapid Titration Method	Jackson (1973)
Soil Ph	Digital pH meter (1:2.5 soil- water suspension ratio)	Jackson (1973)

3.2 CHARACTERISATION AND EVALUATION OF SELECTED CLOVE ACCESSIONS

All the identified twenty accessions were subjected to morphological and biochemical characterization.

3.2.1 Qualitative characters

Selected clove accessions were characterized with the help of descriptors. Presently there is no descriptor on clove, hence descriptor of *Garcinia mangostana*, perennial tree crop published by International Plant Genetic Resources Institute, Rome (IPGRI, 2003) and minimal descriptors for tree crops like *Sizigium cumini*

and *Myristica fragrans* published by National Bureau of Plant Genetic Resources, New Delhi were referred (PPVFRA, 2012).

The recorded qualitative characters of clove trees were canopy shape, branching pattern, colour of young leaf, colour of mature leaf, leaf lamina shape, leaf apex shape, leaf arrangement, bud forming season, bud clustering habit, bud size, position of flower, petal colour, sepal colour, colour of stigma, colour of peduncle, colour of hypanthium, fruit shape, mature fruit colour, ripe fruit colour, seed shape and seed colour. Based on the variability noticed in each character, twenty accessions were selected and these characters were recorded.

3.2.1.1 Tree characters

3.2.1.1.1 *Canopy shape*

After surveying of selected clove growing estates, the tree canopy shape of the matured clove trees were classified into elliptic, cylindrical, conical and pyramidical shapes. The tree canopy shape of all twenty selected accessions were recorded.

3.2.1.1.2 Branching pattern

The branching pattern of the more than one thousand five hundred clove plants were observed and three different branching like erect, semi-erect and irregular type were noticed. The selected twenty accessions were grouped under erect, semi-erect or irregular type.

3.2.1.2 Leaf characters

3.2.1.2.1 Color of young leaf

The young leaf color of twenty clove accessions were observed as per the Royal Horticulture Society Color Chart and were grouped into red pink with light green tinge, yellow green with light green tinge and purple red with light green tinge.

3.2.1.2.2 Color of mature leaf

The fully mature leaf color of twenty accessions were grouped into green and dark green.

3.2.1.2.3 Leaf lamina shape

The leaf lamina shape was recorded after clear visual observation done on clove leaf bearing shoots. Leaf lamina shape of twenty accessions were recorded from second fully opened opposite leaf pair from bud at the tip of the branch.

3.2.1.2.4 Leaf apex shape

The mature leaf apex shape of second fully opened opposite leaf pair was recorded on visual observation.

3.2.1.2.5 Leaf arrangement

The pattern of arrangement of leaves on the shoot of the branches was recorded on visual observation.

3.2.1.3 Bud, flower, fruit and seed characters

3.2.1.3.1 Bud forming season

Peak bud forming period was considered as the season of bud forming. Season of bud forming was grouped into early (late October to late November), mid (December to January) and late (February to March) season types.

3.2.1.3.2 Bud clustering habit

It was recorded by counting the number of flower buds per cluster.

3.2.1.3.3 Bud size

Bud size was measured at bud harvesting period when they turn slight pinkish color. It was categorized as small, medium and large.

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3.2.1.3.4 Position of flower

It was recorded as inflorescence arising position in the flowering part of the plant by visual observation.

3.2.1.3.5 Petal color

The color of petal was recorded when the four connected petals separate as a cap from the hypanthium of the clove flower. Color was recorded as per the Royal Horticulture Society Color Chart.

3.2.1.3.6 Sepal color

The color of fleshy sepal was recorded as per the Royal Horticulture Society Color Chart.

3.2.1.3.7 Color of stigma

The color of stigma was recorded as per the Royal Horticulture Society Color Chart.

3.2.1.3.8 Color of peduncle

The color of peduncle was recorded as per the Royal Horticulture Society Color Chart.

3.2.1.3.9 Color of hypanthium

The color of hypanthium was recorded as per the Royal Horticulture Society Color Chart.

3.2.1.3.10 Fruit shape

The shape of the fruit was observed visually during fruiting season. It was categorized as elliptical and oblong shapes.

3.2.1.3.11 Mature fruit color

The color of the mature fruit was recorded as per the Royal Horticulture Society Color Chart.

3.2.1.3.12 Ripe fruit color

The color of the fully ripened fruit was assigned as per the Royal Horticulture Society Color Chart.

3.2.1.3.13 Seed shape

The shape of the seed was recorded on visual observation after extracting the seed from the ripened fruit. It was categorized as elliptical and oblong shapes.

3.2.1.3.14 Seed color

The color of the seed was recorded as per the Royal Horticulture Society Color Chart.

3.2.2 Quantitative characters

3.2.2.1 Tree characters

3.2.2.1.1 Plant height

The height of the selected fully mature tree was measured from the base of the tree to the highest tip of the tree canopy with the help of Smart measure android application (Smart measure 1.6.7 for android) and measuring tape. It was expressed in metres (m).

3.2.2.1.2 Girth at 45 cm height

The girth of the tree trunk was recorded at 45 centimeters height from above the ground level with the help of measuring tape and values expressed in centimeters.

3.2.2.1.3 Canopy spread (N-S & E-W)

Tree canopy spread was measured as maximum canopy spreading both North - South and East - West direction using a measuring tape.

3.2.2.1.4 Number of branches

The number of main branches were counted in selected clove accessions.

3.2.2.2 Leaf characters

3.2.2.2.1 Leaf length

Average length of twenty fully matured leaves were measured from the leaf base to the tip of lamina excluding petiole. It was collected from matured fully opened second opposite leaf pair from tip of bearing shoot from all the four sides with a representative sample size of five each and expressed in centimetres (cm).

3.2.2.2.2 Leaf breadth

Leaf breadth was recorded on twenty fully opened leaves at widest middle portion of leaf blade. It was collected from matured second opposite leaf pair from tip of bearing shoot from all the four sides with a representative sample size of five each and expressed in centimetres (cm).

3.2.2.2.3 Leaf area

Leaf area was recorded by using graph paper method. It was measured on the twenty same leaves which were used for taking length and breadth observations and expressed in cm^2.

3.2.2.3 Bud, flower, fruit and seed characters

3.2.2.3.1 Number of inflorescence/m^2

Number of inflorescence/m^2 was measured by counting the number of inflorescence per m^2 area by fixing 1 m^2 quadrats on all four sides of the selected trees.

3.2.2.3.2Number of flower buds/inflorescence

Number of flower buds/inflorescence was measured by counting the number of clove flower buds per inflorescence from all the four sides with a representative sample size of five inflorescence in each side of the selected trees and the mean value was expressed.

3.2.2.3.3 Length of flower

The average length of ten flowers for each selected accession was measured by using digital Vernier Caliper (HAWK HT0472) and mean value was expressed in cm.

3.2.2.3.4 Breadth of flower

The mean breadth of ten flowers per accessions were recorded on the same flower used for measuring the flower length from the widest part of the flower and mean value was expressed in cm.

3.2.2.3.5 Number of petal

Number of petals were measured by counting the number of petals in a flower and by selecting ten fully opened flower on all four sides of the selected trees and mean value was expressed.

3.2.2.3.6 Number of sepal

Number of sepals were recorded by counting the number of sepals per flower which were collected from all four sides of the selected trees and the mean value was expressed.

3.2.2.3.7 Length of petal

The length of ten petals were recorded from the base to the tip of petal with the help of digital Vernier Caliper (HAWK HT0472) and mean value was expressed in mm.

3.2.2.3.8 Length of sepal

The length of ten sepals were measured from the tip of sepal to top of hypanthium by using digital Vernier Caliper (HAWK HT0472) and expressed in mm.

3.2.2.3.9 Single bud weight (fresh)

Single bud weight (fresh) was recorded by taking the fresh weight of 20 flower buds per tree and calculated the mean and expressed in mg.

3.2.2.3.10 Single bud weight (dry)

Single bud weight (dry) was recorded by taking the dry weight of 20 flower buds after oven drying at 50°C for 15 hours (Murni *et al.*, 2017). Same flower buds which were used for measuring fresh weight of single bud were used for taking dry weight and the mean value was calculated and expressed in mg.

3.2.2.3.11 Mature bud length

Mean length of 20 mature buds were recorded from the base to the tip of flower bud with the help of digital Vernier Caliper (HAWK HT0472) and expressed in mm.

3.2.2.3.12 Mature bud diameter

Diameter of the mature bud was measured by recording the mean head width of 20 flower buds and expressed in mm.

3.2.2.3.13 Period from bud initiation to bud harvest

The number of days taken from bud initiation to bud harvest period was recorded from ten buds and mean value was expressed.

3.2.2.3.14 Bud yield per tree (fresh)

Fresh bud yield per tree of selected accessions were recorded during 2017 and 2018 and the average was expressed in kg/tree.

3.2.2.3.15 Bud yield per tree (dry)

Dry bud yield per tree of selected accessions were recorded after sun drying during 2017 and 2018 and mean expressed in kg/tree.

3.2.2.3.16 Fruit weight (fresh)

Mean fresh weight of twenty representative fruit samples per accessions were recorded and expressed in grams.

3.2.2.3.17 Ratio of fruit to seed

The fresh weight of twenty representative fruit and seed was weighed and the ratio of fruit to seed was the proportion of fruit weight to the seed weight. The mean ratio was found out and expressed.

3.2.2.3.18 Seed length

Mean length of ten fresh seeds per accession were recorded after extracting from freshly harvested fruits and expressed in cm.

3.2.2.3.19 Seed breadth

Breadth of ten fresh seeds per accession were recorded and mean breadth was expressed in cm.

3.2.2.3.20 Seed weight

Average seed weight of ten seeds per accession were recorded and expressed in grams.

3.2.2.3.21 Time taken for harvest of fruit from flowering

Time taken for harvest of fruit from flowering was recorded by counting the number of days taken from flowering to harvesting of the ripe fruits. It was done by marking five flower buds per tree.

3.2.2.4 Quality parameters

The clove buds and stem of selected 20 accessions were analyzed for both essential oil, oleoresin and eugenol content. After extracting volatile oil, the volatile oil of all the accessions were subjected to GC profiling.

3.2.2.4.1 Bud oil

The essential oil present in flower bud was extracted by hydro distillation method using modified Clevenger apparatus (Pruthi, 1999). Twenty-five gram of dried clove flower bud was powdered and mixed with 500 ml of distilled water. Mixture of sample and water was subjected to hydro distillation for 4 hours with temperature ranging between 60 °C to 70 °C. The collected oil was left in the apparatus receiver for overnight and cooled to room temperature. The oil collected were dried by adding a pinch of anhydrous sodium sulphate. The volume of the oil collected was expressed as per cent volume per unit mass of the sample.

$$\text{Bud volatile oil (\%)} = \frac{\text{Volume of the volatile oil collected}}{\text{Total weight of the sample (g)}} \times 100$$

3.2.2.5.2 Bud Oleoresin

The clove bud oleoresin was extracted through solvent extraction method by using Soxhlet apparatus and by using petroleum benzene as solvent. Five gram of dried clove flower bud sample was powdered and packed in a thimble. Seventy-five millilitres of petroleum benzene was taken in the round bottom flask of the apparatus. Thimble was placed in Soxhlet extraction tube. Solvent was subjected to boiling and extraction continued for three to four hours till no color was observed for the solvent in extraction tube. At the final stage removed the thimble and repeated the distillation process to remove all the solvents. Oleoresin was collected at round bottom flask of the apparatus and expressed in percentage (ASTA, 1968).

$$\text{Bud oleoresin (\%)} = \frac{\text{Weight of oleoresin extracted}}{\text{Initial weight of the sample}} \times 100$$

3.2.2.5.3 Stem oil

The essential oil present in stem (Inflorescence stalk) was extracted by hydro distillation method using modified Clevenger apparatus (Pruthi, 1999). Twenty-five gram of dried inflorescence stalk was powdered and mixed with 500 ml of distilled water. Mixture of sample and water was subjected to hydro distillation for 4 hours with temperature ranging between 60 °C to 70 °C. The collected oil was left in the apparatus receiver for overnight and cooled to room temperature. The oil collected were dried by adding a pinch of anhydrous sodium sulphate. The volume of the oil collected was expressed as per cent volume per unit mass of the sample.

$$\text{Bud volatile oil (\%)} = \frac{\text{Volume of the volatile oil collected}}{\text{Total weight of the sample (g)}} \times 100$$

3.2.2.5.4 Stem Oleoresin

The clove stem (Inflorescence stalk) oleoresin was extracted through solvent extraction method by using Soxhlet apparatus by using petroleum benzene solvent. Five gram of dried inflorescence stalk was powdered and packed in a thimble. Seventy-five millilitres of petroleum benzene was taken in the round bottom flask of the apparatus. Thimble was placed in Soxhlet extraction tube. Solvent was subjected to boiling and extraction continued for three to four hours till no color was observed for the solvent in extraction tube. At the final stage removed the thimble and repeated the distillation process to remove all the solvents. Oleoresin was collected at round bottom flask of the apparatus and expressed in percentage (ASTA, 1968).

$$\text{Stem oleoresin (\%)} = \frac{\text{Weight of oleoresin extracted}}{\text{Initial weight of the sample}} \times 100$$

3.2.2.5.5 Eugenol content of bud

Various methods are followed in the isolation process of eugenol. In the present investigation, eugenol content of all the selected twenty accessions were estimated by GC-MS analysis.

3.2.2.5.6 GC Profiling of elite accessions

The volatile oils of twenty selected clove accessions were subjected to Gas chromatography Mass spectroscopy (GC MS) analysis. GC MS of the oil samples was recorded in an instrument GC-Varian 3800 coupled with 4000 MS, TQD with Ion Trap. The extracted essential oil was diluted accordingly with the appropriate solvent and inserted desired quantity in the GC to get resolved on the column. Subsequently, sample is injected into the injector port for GC analysis and allowed remaining there in the inlet for 15 min. The MS column was fused-silica capillary column of 30 m x 0.25 mm id, 0.25 mm film thickness for the analysis. The injector

temperature was set at 250ºC and all injections were either split-less or in split (1:20) mode for 0.5 min followed by split-less. The detector temperature was set to 270°C, and the temperature programmes for column was as follows: 40°C for 3 min at an increment 3°C/min to 190°C, hold for 1 min, then 5°C/min to 220°C and maintaining the constant temperature for 5 min. 170 Operate the mass spectrometer in the external electron ionization mode with the carrier gas helium 1 ml/min; injector temperature, 250°C; trap temperature 180°C, ion source-heating at 190°C, transfer line temperature 260°C, EI-mode at 70 eV, with full scan-range 50-350 amu. The total volatile production was calculated by the sum of all GC peak areas in the chromatogram and expressed individual compounds as relative percent area and the compounds can be identified by comparing the retention index which were determined by using homologous series of n-alkanes (C5 to C32) as standard and comparing the spectra using two spectral libraries available as Wiley and NIST-2007 library.

3.2.3. Incidence diseases

The selected trees were monitored for any incidence of diseases during the experimental period of one year.

3.2.4. Incidence pest

The selected trees were monitored for any incidence of pests during the experimental period of one year.

3.3 STATISTICAL ANALYSIS

The data generated from the experiment were analyzed statistically using standard procedures. Appropriate statistical analysis like NTSYS (Numerical Taxonomy System) package for clustering of qualitative characters and multivariate analysis for quantitative clustering was done.

RESULTS

4. RESULTS

A purposive survey was conducted for characterization and evaluation of clove accessions in the major clove growing plantations at Trivandrum, Kollam and Pathanamthitta districts of Kerala and Kanyakumari district of Tamil Nadu, so as to comprehend the varied aspects of clove. Till date no detailed cataloguing of the varied features of clove has been reported.

Clove is a perennial tree spice and the growth and yield of the plant can be understood only if we know the conditions under which the crop was grown. Hence, a detailed investigation of location and the soil nutrient status of selected clove accessions were recorded. The present chapter outlines the details of survey, morphological and biochemical characterisation of selected clove accessions.

4.1. SURVEY

The survey was carried out in fifteen different locations from the clove growing areas of Trivandrum, Kollam and Pathanamthitta districts of Kerala and Kanyakumari district of Tamil Nadu. Survey was carried out to identify clove accessions showing morphological variability, diverse origin, superior yield and unique characters (Table 3). Survey was carried out in the Braemore Estate Limited, Braemore, Merchiston Estate Southern Field Ventures Pvt. Ltd. Ponmudi, Gokul Rubber & Tea Plantations Ltd. Vithura, Marigold Estate, Vardhini Plantations (Pvt) Ltd. Brimore, homesteads of Mr. Simpson, Kallar, Vithura, Coconut Research Station, Balaramapuram, College of Agriculture, Vellayani, from Thiruvananthapuram district, Travancore Rubber and Tea Co. Ltd. Ambanad Estate, Ambanad, Infield Estate Harrisons Malayalam Limited, Thenmala, District Agriculture Farm, Anchal from Kollam district, homesteads of Koshy Simon, Kochannur and Raju Palliachal of Valakuzhy from Pathanamthitta district, Alagappa Estate, Maramalai Hills, Paskadai Estate, Black Rock Hills, State Horticulture Farm and Horticultural Research Station at Pechiparai from Kanyakumari district.

After surveying 1610 plants, accessions which showed special characters and superiority in yield based on survey were selected for characterization and evaluation. Twenty different accessions were identified and labelled as BRC-1, BRC-2, BRC-3, BRC-4, MRC-5, MRC-6, MRC-7, MRC-8, AMC-9, AMC-10, AMC-11, AMC-12, AMC-13, MMC-14, MMC-15, BLC-16, BLC-17, BLC-18, MGC-19 and ANC-20 according to the name of the estates from where the plants were identified. Survey details like location, village, taluk, district, latitude, longitude, altitude, age of plant, habitat, ethnobotanical information, pest and diseases (resistance/susceptibility/tolerance), special characters, manuring, fertilizer application, irrigation and pesticide application of the selected accessions were recorded and presented in table 4a,4b,4c,4d.

4.1.1 Survey details

The Braemore Estate Limited, located in Braemore village of Nedumangad taluk in Thiruvananthapuram district at a latitude of 8°45'51", longitude of 77°05'00" and at an altitude ranging from 441 to 453 m above the mean sea level contained clove plants which showed morphological variation and superior yield as revealed from the survey and first year yield data. From the Braemore Estate Limited, four accessions were selected based on their yield, shape of tree and large sized flower buds and named as BRC-1, BRC-2, BRC-3 and BRC-4. BRC-1, BRC-2 and BRC-3 belonged to the age group of 25 to 30 years while BRC-4 belonged to 35 to 40 year age group. All the four accessions showed less susceptibility to leaf spot disease. Clove plants of this estate were regularly manured and fertilised. However, the clove plants were rainfed and pesticidal application was not practised in the Braemore estate.

Merchiston Estate Southern Field Ventures Pvt. Ltd located in the Ponmudi village of Nedumangad taluk was another estate selected in the Thiruvananthapuram district. The estate is located at a latitude from 8°44'34" to 8°44'39" and a longitude of 77°07'38" to 77°07'39" and at an altitude of 649 m to 653 m. The clove plants selected from this estate were designated as MRC-5, MRC-

6, MRC-7 and MRC-8. These trees belonged to the age group of 30 to 35 years and were less susceptible to leaf spot disease. The clove plants of the estate were manured and fertilised regularly. However, the plants were not irrigated and pesticide application was not undertaken in the plantation.

From the Kollam district, Ambanad Estate of Travancore Rubber & Tea Co. Ltd. which belonged to Aryancavu village of Punalur taluk located at a latitude ranging from 9°01'13" to 9°02'23" and longitude ranging from 77°06'00" to 77°06'41" at an altitude of 377 m to 669 m was selected for the study. Five clove accessions selected from this estate were designated as AMC-9, AMC-10, AMC-11, AMC-12 and AMC-13 and belonged to the age group of 25 to 30 years. AMC-9 showed least incidence of leaf spot and hence the accession may be more tolerant or resistant to leaf spot disease and had ornamental type of pink coloured clove bud. All other selected accessions showed less susceptibility to leaf spot disease. AMC-10 was reported as a good yielder and AMC-11 was selected due to the pyramidical shape and more number of branches observed. The clove plants were manured and fertilised regularly. The clove plants in the estate were rainfed and pesticidal application was not common. AMC-12 had small sized clove buds but was reported as regular bearer. AMC-13 was selected due to the bold cloves observed from the accession.

In the Pathanamthitta district, clove plantations were not common and hence, individual clove plants which were grown in the homesteads were surveyed. These plants were the normal ones which were maintained without much care and hence selection was not made from the district.

As part of the survey many clove growing estates like Maramalai, Alagappa and Pasukadai estates as well as State Horticultural Farm of Kanyakumari district were visited. From these cloves growing locations, those clove plants maintained well were taken for the study. Two accessions from Alagappa estate were named as MMC-14 and MMC-15. The estate belonged to Surulacode village of Kalkulam taluk. The estate was located at a latitude of 8°22'33" and longitude of 77°27'20"

at an altitude of 753 m. The clove accession MMC-14 belonged to age group of 25-30 years and very few incidence of leaf spot was observed unlike other plants, suggesting leaf spot tolerance nature of the accession. MMC-15 belonged to the age group of 30-35 years and was less susceptible to leaf spot. Both the accessions were good yielders. Manuring and fertiliser application was seen in the plantation and the plantation was irrigated but no pesticides were applied. Three accessions were selected from the Pasukadai Estate situated at Gnalam village of Thovala Taluk. The estate is located at a latitude of 8°26'44" and longitude of 77°24'28" at an altitude of 848 m above the mean sea level. Three accessions were selected from this estate and designated as BLC-16, BLC-17 and BLC-18 and belonged to age group of 25 to 40 years. Manuring and fertiliser application was practised in the plantation and the clove plants were irrigated. BLC 16 was reported as a good yielder while BLC-17 was reported as an early maturing one and BLC-18 had a cylindrical tree shape.

MGC-19 was the accession selected from Marigold Estate, Vardhini plantations (P) Ltd. of Brimore village from Nedumangad taluk of Thiruvananthapuram district. The estate was located at a latitude of 8°45'16" and longitude of 77°05'18" and at an altitude of 280 m above mean sea level. MGC-19 belonged to age group of 30-35 years and was having cylindrical shape with single stem. Manuring was given to the clove accession, but fertiliser application was not common. The plant was rainfed and pesticide application was not practised.

ANC 20 was the accession selected from District Agricultural Farm, Kottukkal. The farm is located in Anchal village of Punalur taluk in Kollam district at a latitude of 8°54'04" and longitude of 76°55'13" at an altitude of 45 m above the mean sea level. The plant belonged to the age group of 30-35 years with single stem and small buds. The plant was rainfed and manured regularly but fertiliser and pesticide application was not usually followed. The twenty selected clove accessions were observed for their qualitative and quantitative characters. The yield was observed for two years *viz.*, 2016-17 and 2017-18.

Table 3. Survey details

Sl. No.	Name of the planter/ Address	Any tree showing variability	Accession number	Number of plants surveyed	Susceptible to Pest/ Disease incidence	Special feature
1	The Braemore estate limited, Braemore, Palode Nedumangad	Yes	BRC-1	300	Yes	Good yield
			BRC-2		Yes	Cylindrical shaped tree
			BRC-3		Yes	Large sized bold flower buds
			BRC-4		No	Good yield
2	Merchiston estate Southern Field Ventures Pvt. Ltd. Ponmudi, Nedumangad	Yes	MRC-5	335	Yes	Good yield, Dense foliage
			MRC-6		Yes	Good yield, Dense foliage
			MRC-7		Yes	Narrowly pyramidical shape
			MRC-8		Yes	Good yield
3	The Gokul Rubber & Tea Plantations Ltd. Vithura, Nedumangad	-	*	20	-	-
4	Marigold estate, Vardhini plantations (P) Ltd. Brimore Road, Brimore, Nedumangad	Yes	MGC-19	25	Yes	Cylindrical shape, Single main stem

Table 3. continued…

Sl. No.	Name of the planter/ Address	Any tree showing variability	Accession number	Number of plants surveyed	Susceptible to Pest/ Disease incidence	Special feature
5	Mr. Simpson, Kallar, Vithura, Nedumangad	NA	*	5	Yes	-
6	Coconut Research Station, Balaramapuram	NA	*	5	Yes	-
7	College of Agriculture, Vellayani	NA	*	3	Yes	-
8	Travancore Rubber & Tea Co. Ltd. Ambanad, Amband estate, Punalur	Yes	AMC-9	600	Yes	Pink coloured clove bud, Ornamental type
			AMC-10		Yes	Good yielder
			AMC-11		Yes	Pyramidical shape, Highly branched tree
			AMC-12		Yes	Small sized clove buds, Regular bearer
			AMC-13		Yes	Bold buds
9	Infield estate Harrisons Malayalam Limited, Thenmala, Punalur	NA	*	35	Yes	-

Table 3. continued…

Sl. No.	Name of the planter/ Address	Any tree showing variability	Accession number	Number of plants surveyed	Susceptible to Pest/ Disease incidence	Special feature
10	District Agriculture Farm, Kottukkal, Anchal, Punaloor	Yes	ANC-20	9	Yes	Single stem, Small flower buds
11	Alagappa estate, Maramalai Hills, Keeriparai, Kanyakumari	Yes	MMC-14	150	Yes	Good yield
			MMC-15		Yes	Good yield
12	Paskadai estate, Gnalam, Thovalai, Kanyakumari	Yes	BLC-16	80	Yes	Good yield
			BLC-17		Yes	Early maturing
			BLC-18		Yes	Cylindrical tree shape
13	State Horticulture Farm, Pechiparai, Kanyakumari	-	*	8	Yes	-
14	Koshy Simon Acharicheril, Kochannur P.O, Pathanamthitta	-	*	25	Yes	-
15	Raju Palliachal Valakuzhy, Pathanamthitta	-	*	10	Yes	-

'*' denotes no accessions that met the purpose of the study

Table 4 a. Passport data of the selected clove accessions

Sl. no.	Accession ID	Location	Village	Taluk	District
1	BRC-1	The Braemore Estate Limited, Braemore	Braemore	Nedumangad	Thiruvananthapuram
2	BRC-2	The Braemore Estate Limited, Braemore	Braemore	Nedumangad	Thiruvananthapuram
3	BRC-3	The Braemore Estate Limited, Braemore	Braemore	Nedumangad	Thiruvananthapuram
4	BRC-4	The Braemore Estate Limited, Braemore	Braemore	Nedumangad	Thiruvananthapuram
5	MRC-5	Merchiston Estate Southern Field Ventures Pvt. Ltd.	Ponmudi	Nedumangad	Thiruvananthapuram
6	MRC-6	Merchiston Estate Southern Field Ventures Pvt. Ltd.	Ponmudi	Nedumangad	Thiruvananthapuram
7	MRC-7	Merchiston Estate Southern Field Ventures Pvt. Ltd.	Ponmudi	Nedumangad	Thiruvananthapuram
8	MRC-8	Merchiston Estate Southern Field Ventures Pvt. Ltd.	Ponmudi	Nedumangad	Thiruvananthapuram
9	AMC-9	Travancore Rubber & Tea Co. Ltd. Ambanad Estate, Amband	Aryancavu	Punalur	Kollam
10	AMC-10	Travancore Rubber & Tea Co. Ltd. Ambanad Estate, Amband	Aryancavu	Punalur	Kollam
11	AMC-11	Travancore Rubber & Tea Co. Ltd. Ambanad Estate, Amband	Aryancavu	Punalur	Kollam
12	AMC-12	Travancore Rubber & Tea Co. Ltd. Ambanad Estate, Amband	Aryancavu	Punalur	Kollam
13	AMC-13	Travancore Rubber & Tea Co. Ltd. Ambanad Estate, Amband	Aryancavu	Punalur	Kollam
14	MMC-14	Alagappa Estate, Surlacode	Surulacode	Kalkulam	Kanyakumari

Sl. no.	Accession ID	Location	Village	Taluk	District
15	MMC-15	Alagappa Estate, Surlacode	Surulacode	Kalkulam	Kanyakumari
16	BLC-16	Pasukadai Estate, Gnalam	Gnalam	Thovala	Kanyakumari
17	BCL-17	Pasukadai Estate, Gnalam	Gnalam	Thovala	Kanyakumari
18	BLC-18	Pasukadai Estate, Gnalam	Gnalam	Thovala	Kanyakumari
19	MGC-19	Marigold Estate, Vardhini plantations (P) Ltd. Braemore	Braemore	Nedumangad	Thiruvananthapuram
20	ANC-20	District Agricultural Farm, Kottukkal	Anchal	Punalur	Kollam

Table 4b. Passport data of the selected clove accessions

Sl. no.	Accession ID	Latitude	Longitude	Altitude (m)	Age of the plant (Years)
1	BRC-1	8°45'51"	77°05'00"	453 m	25-30
2	BRC-2	8°45'51"	77°05'00"	453 m	25-30
3	BRC-3	8°45'51"	77°05'00"	441 m	35-40
4	BRC-4	8°45'51"	77°05'00"	441m	25-30
5	MRC-5	8°44'35"	77°07'38"	653 m	30
6	MRC-6	8°44'35"	77°07'38"	653 m	30
7	MRC-7	8°44'34"	77°07'38"	651 m	30-35
8	MRC-8	8°44'39"	77°07'39"	649 m	30-35
9	AMC-9	9°02'16"	77°06'41"	669 m	25-30
10	AMC-10	9°02'16"	77°06'24"	643 m	25-30
11	AMC-11	9°02'17"	77°06'25"	652 m	25-30
12	AMC-12	9°02'23"	77°06'24"	607 m	25-30
13	AMC-13	9°01'13"	77°06'00"	377 m	25-30
14	MMC-14	8°22'33"	77°27'20"	753 m	25-30
15	MMC-15	8°22'33"	77°27'20"	753 m	30-35
16	BLC-16	8°26'44"	77°24'28"	848 m	35-40
17	BCL-17	8°26'44"	77°24'28"	848 m	25-30
18	BLC-18	8°26'44"	77°24'28"	850m	35-40
19	MGC-19	8°45'16"	77°05'18"	280 m	30-35
20	ANC-20	8°54'04"	76°55'13"	45 m	30-35

Table 4c. Passport data of the selected clove accessions

Sl. no.	Accession ID	Habitat	Ethnobotanical information	Pest and Diseases (Resistance/ Susceptibility/ Tolerance)
1	BRC-1	Cultivated	It is used in the culinary preparation and helps against bad breath.	Less susceptible to leaf spot disease
2	BRC-2	Cultivated		Less susceptible to leaf spot disease
3	BRC-3	Cultivated		Less susceptible to leaf spot disease
4	BRC-4	Cultivated		Less susceptible to leaf spot disease
5	MRC-5	Cultivated	Against toothache and used in the culinary preparation	Less susceptible to leaf spot disease
6	MRC-6	Cultivated		Less susceptible to leaf spot disease
7	MRC-7	Cultivated		Less susceptible to leaf spot disease
8	MRC-8	Cultivated		Less susceptible to leaf spot disease
9	AMC-9	Cultivated	Biting of 1-2 clove buds improves the digestion and reduces the toothache. It is used in the culinary preparation	Tolerant to leaf spot disease
10	AMC-10	Cultivated		Less susceptible to leaf spot disease
11	AMC-11	Cultivated		Less susceptible to leaf spot disease
12	AMC-12	Cultivated		Less susceptible to leaf spot disease
13	AMC-13	Cultivated		Less susceptible to leaf spot disease
14	MMC-14	Cultivated	It is used in the culinary preparation. Against toothache.	Tolerant to leaf spot disease
15	MMC-15	Cultivated		Less susceptible to leaf spot disease
16	BLC-16	Cultivated	It helps against bad breath, and tooth ache.	Less susceptible to leaf spot disease
17	BCL-17	Cultivated		Less susceptible to leaf spot disease

Sl. no.	Accession ID	Habitat	Ethnobotanical information	Pest and Diseases (Resistance/ Susceptibility/ Tolerance)
18	BLC-18	Cultivated	It helps against bad breath, and tooth ache.	Less susceptible to leaf spot disease
19	MGC-19	Cultivated	It is used in the culinary preparation	Less susceptible to leaf spot disease
20	ANC-20	Cultivated	It is used in the culinary preparation	Less susceptible to leaf spot disease

Table 4d. Passport data of the selected clove accessions

Sl. no.	Accession ID	Special characters if any	Manuring	Fertilizer application	Irrigation	Pesticide application
1	BRC-1	Good yield	Yes	Yes	No	No
2	BRC-2	Cylindrical shaped tree	Yes	Yes	No	No
3	BRC-3	Large sized bold flower buds	Yes	Yes	No	No
4	BRC-4	Good yield	Yes	Yes	No	No
5	MRC-5	Good yield, Dense foliage	Yes	Yes	No	No
6	MRC-6	Good yield, Dense foliage	Yes	Yes	No	No
7	MRC-7	Narrowly pyramidical shape	Yes	Yes	No	No
8	MRC-8	Good yield	Yes	Yes	No	No
9	AMC-9	Pink coloured clove bud, Ornamental type	Yes	Yes	No	No
10	AMC-10	Good yielder	Yes	Yes	No	No
11	AMC-11	Pyramidical shape, Highly branched tree	Yes	Yes	No	No
12	AMC-12	Small sized clove buds, Regular bearer	Yes	Yes	No	No
13	AMC-13	Bold buds	Yes	Yes	No	No
14	MMC-14	Good yield	Yes	Yes	Yes	No
15	MMC-15	Good yield	Yes	Yes	Yes	No
16	BLC-16	Good yield	Yes	Yes	Yes	No
17	BCL-17	Early maturing	Yes	Yes	Yes	No
18	BLC-18	Cylindrical tree shape	Yes	Yes	Yes	No
19	MGC-19	Cylindrical shape, Single main stem	Yes	No	No	No
20	ANC-20	Single stem, Small flower buds	Yes	No	No	No

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Ethnobotanical information was collected from the selected estates on enquiry with the estate owners and the people working in the estates.

4.2. Soil analysis

The soil condition plays a major role for the robust establishment of a plantation. The soil parameters namely N, P, K, organic carbon and soil pH were recorded as envisaged in the study and the recommended nutrients were applied based on the soil test data. The results of soil nutrient status as well as soil pH is presented in table 5. Fertilizer application was undertaken based on the soil nutrient status and detailed in the appendix I and II.

4.3 CHARACTERISATION AND EVALUATION OF SELECTED CLOVE ACCESSIONS

The qualitative and quantitative characterization were carried out in the selected clove accessions.

Due to non availability of the developed descriptor for clove, descriptors of other perennial crops published by National Bureau of Plant Genetic Resources, New Delhi and International Plant Genetic Resources Institute (PPVFRA, 2012 and IPGRI, 2003) were referred. For assigning the colour for qualitative characters, Royal Horticulture Society colour chart was used.

4.3.1 Qualitative characterization

The qualitative characters observed in the selected accessions included tree, leaf, bud, flower, fruit and seed characters. Considerable variation was present among the accessions for 15 out of 21 qualitative characters observed. Few characters like leaf arrangement, position of flower, colour of peduncle, mature fruit colour, ripe fruit colour and seed colour were non variable characters among the accessions. Hence these characters were not included for further analysis.

Table 5. Status of soil nutrients and soil pH before the application of fertilizers

Sl. No.	Accessions ID	Soil nutrients before the application of fertilizers				Soil pH
		N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	Organic Carbon (%)	
1	BRC-1	181.83	5.83	247.96	0.69	4.1
2	BRC-2	554.2	9.8	334.2	2.58	3.56
3	BRC-3	296.18	14.22	220.33	1.4	4.02
4	BRC-4	402.2	8.88	244.6	2.1	3.8
5	MRC-5	163.86	8.67	293.88	0.45	5.1
6	MRC-6	310.83	5.18	267.65	1.1	4.8
7	MRC-7	363.8	23.78	310.72	1.4	4.86
8	MRC-8	323.84	6.24	198.2	1.25	5.53
9	AMC-9	390.5	16.10	392.3	1.6	4.2
10	AMC-10	406.62	24.1	350.1	2.1	4.57
11	AMC-11	576.8	33.35	306.44	2.6	3.7
12	AMC-12	410.7	22.4	339.12	2.1	5.5
13	AMC-13	345.4	4.70	287.27	1.8	5.1
14	MMC-14	610.08	6.83	194.99	2.8	3.66
15	MMC-15	543.11	10.5	119.41	2.5	3.9
16	BLC-16	408.15	12.22	183.3	2.1	4.06
17	BLC-17	396.5	7.95	240	1.9	4.3
18	BLC-18	378.44	8.96	203.9	2.0	4.22
19	MGC-19	351.85	5.71	267.68	1.35	5.2
20	ANC-20	311.70	11.81	126.45	1.1	5.55

4.3.1.1 Tree characters

4.3.1.1.1 Canopy shape

The canopy shape observed in the selected clove accessions included elliptical, cylindrical, conical and pyramidical shapes. Among the accessions evaluated, majority of the trees possessed elliptical shapes (40%) followed by cylindrical (20%), conical (20%) or pyramidical shapes (20%). Expressions of canopy shape is presented in the plate 3.

4.3.1.1.2 Branching pattern

Erect, semi-erect and irregular types of branching pattern were observed in the selected clove accessions (Plate 4). Semi-erect pattern (55%) was common, followed by irregular (35%) and erect (10%).

4.3.1.2 Leaf characters

4.3.1.2.1 Colour of young leaf

The colour of young leaf among the selected and evaluated accessions were red pink with light green tinge in 85 %, followed by yellow green with light green tinge (10 %) and purple red with light green tinge in 5 % (Plate 5).

4.3.1.2.2 Colour of mature leaf

The colour of mature leaf observed in the selected clove accessions were green and dark green. Among the twenty evaluated accessions sixty five per cent were dark green and the rest were green (35%). Expressions of mature leaf colour is given in the plate 6.

4.3.1.2.3 Leaf lamina shape

A slight variation was observed among the accessions evaluated for leaf lamina shape. The predominant leaf lamina shape was lanceolate (85%) followed by narrowly elliptical (15%). Expressions of canopy shape is presented in the plate 7.

Table 6. Tree characters of selected clove accessions

Sl. no.	Accessions ID	Canopy shape	Branching pattern
1	BRC-1	Elliptical	Semi-erect
2	BRC-2	Cylindrical	Semi-erect
3	BRC-3	Conical	Semi-erect
4	BRC-4	Elliptical	Irregular
5	MRC-5	Pyramidical	Irregular
6	MRC-6	Pyramidical	Irregular
7	MRC-7	Conical	Semi-erect
8	MRC-8	Elliptical	Semi-erect
9	AMC-9	Elliptical	Irregular
10	AMC-10	Conical	Semi-erect
11	AMC-11	Pyramidical	Irregular
12	AMC-12	Elliptical	Semi-erect
13	AMC-13	Pyramidical	Irregular
14	MMC-14	Elliptical	Semi-erect
15	MMC-15	Elliptical	Semi-erect
16	BLC-16	Conical	Irregular
17	BLC-17	Elliptical	Semi-erect
18	BLC-18	Cylindrical	Semi-erect
19	MGC-19	Cylindrical	Erect
20	ANC-20	Cylindrical	Erect

Elliptical

Cylindrical

Conical

Pyramidical

Plate 3. Expressions of canopy shape

Erect

Semi-erect

Irregular

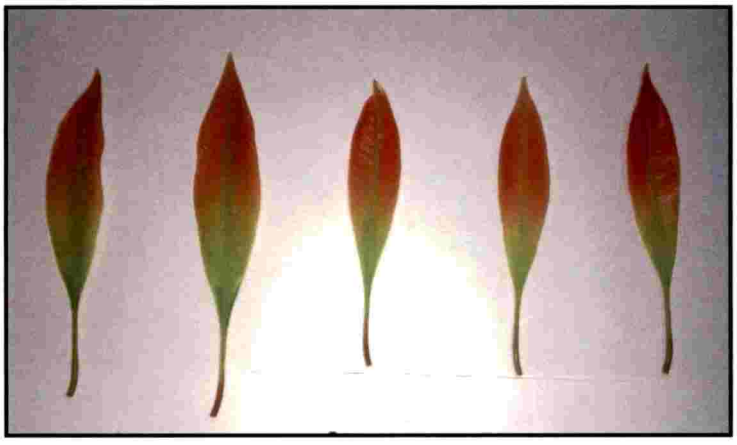
Plate 4. Expressions of branching habit

Table 7. Distribution of tree characters among the selected clove accessions

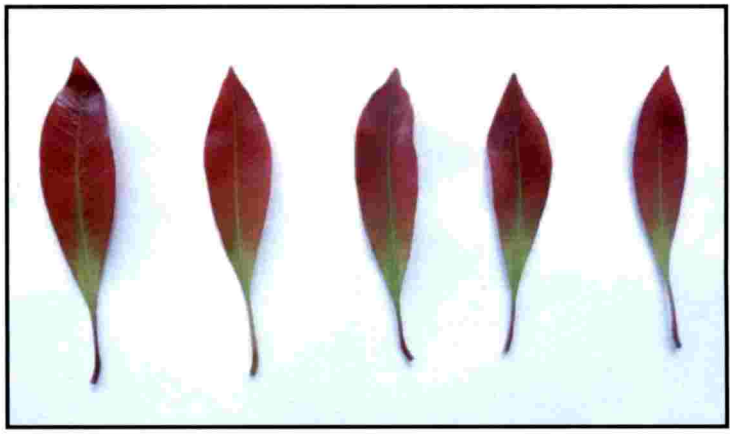
Sl. No.	Character	Expression	Frequency (%)
1	Canopy Shape	Elliptical	40
		Cylindrical	20
		Conical	20
		Pyramidical	20
2	Branching Pattern	Erect	10
		Semi-erect	55
		Irregular	35

Table 8a. Leaf characters of selected clove accessions

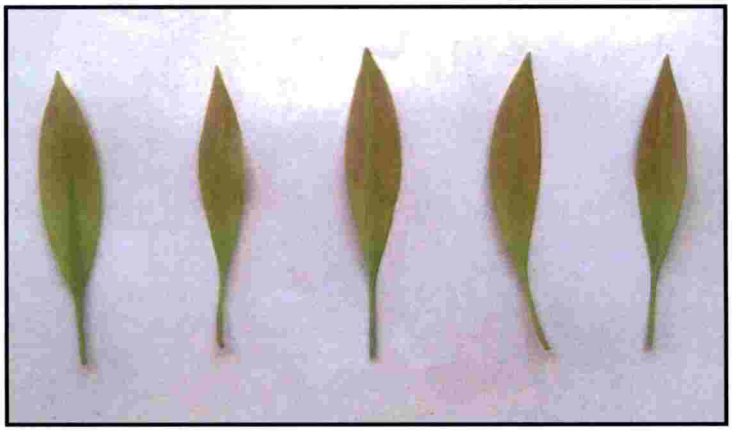
Sl. No.	Accessions ID	Colour of young leaf	RHS Colour chart code	Colour of mature leaf	RHS Colour chart code
1	BRC-1	Red pink with light green tinge	43 A	Green	130 A
2	BRC-2	Red pink with light green tinge	43 A	Dark green	130 A
3	BRC-3	Red pink with light green tinge	43 B	Dark green	130 A
4	BRC-4	Red pink with light green tinge	43 A	Dark green	134 A
5	MRC-5	Red pink with light green tinge	43A	Dark green	134 A
6	MRC-6	Red pink with light green tinge	43A	Dark green	134 A
7	MRC-7	Red pink with light green tinge	43 A	Green	130 A
8	MRC-8	Red pink with light green tinge	43 A	Dark green	132 B
9	AMC-9	Purple red with light green tinge	N 57A	Green	130 A
10	AMC-10	Red pink with light green tinge	43 A	Dark green	134 A
11	AMC-11	Red pink with light green tinge	43 A	Dark green	134 A
12	AMC-12	Red pink with light green tinge	43 A	Green	130 A
13	AMC-13	Red pink with light green tinge	43 A	Dark green	134 A
14	MMC-14	Red pink with light green tinge	43 A	Dark green	132 B
15	MMC-15	Red pink with light green tinge	43 A	Dark green	134 A
16	BLC-16	Red pink with light green tinge	43 B	Dark green	134 A
17	BLC-17	Red pink with light green tinge	43 A	Green	130 A
18	BLC-18	Red pink with light green tinge	43 A	Dark green	134 A
19	MGC-19	Yellow green with light green tinge	149A	Green	130 A
20	ANC-20	Yellow green with light green tinge	149A	Green	130 A



Red pink with light green tinge (Code: 43 A)



Purple red with light green tinge (Code: N 57A)

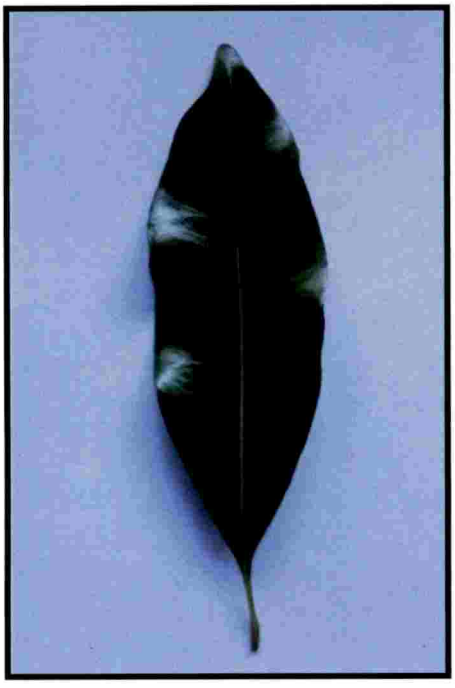


Yellow green with light green tinge (Code: 149 A)

Plate 5. Expressions of colour of young leaf

Table 8b. Leaf characters of selected clove accessions

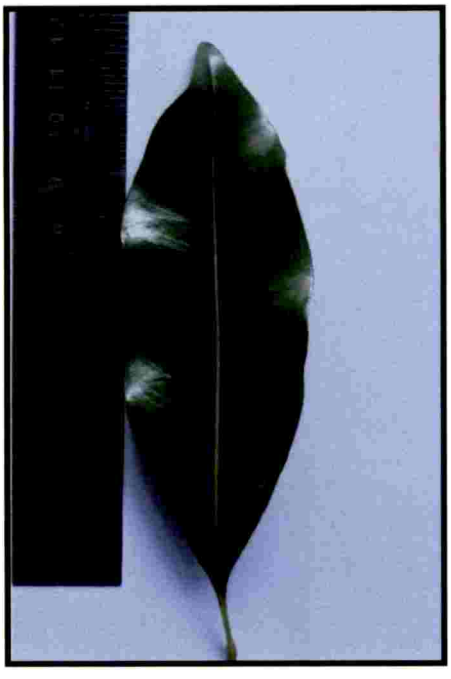
Sl. no.	Accessions ID	Leaf lamina shape	Leaf apex shape
1	BRC-1	Lanceolate	Acuminate
2	BRC-2	Lanceolate	Acuminate
3	BRC-3	Narrowly elliptic	Acute
4	BRC-4	Lanceolate	Acuminate
5	MRC-5	Lanceolate	Acuminate
6	MRC-6	Lanceolate	Acuminate
7	MRC-7	Lanceolate	Acuminate
8	MRC-8	Lanceolate	Acuminate
9	AMC-9	Lanceolate	Acuminate
10	AMC-10	Lanceolate	Acuminate
11	AMC-11	Narrowly elliptic	Acute
12	AMC-12	Lanceolate	Acuminate
13	AMC-13	Narrowly elliptic	Acute
14	MMC-14	Lanceolate	Acuminate
15	MMC-15	Lanceolate	Acuminate
16	BLC-16	Lanceolate	Acuminate
17	BLC-17	Lanceolate	Acuminate
18	BLC-18	Lanceolate	Acuminate
19	MGC-19	Lanceolate	Acuminate
20	ANC-20	Lanceolate	Acuminate



Dark green (Code: 134 A)

Green (Code: 130 A)

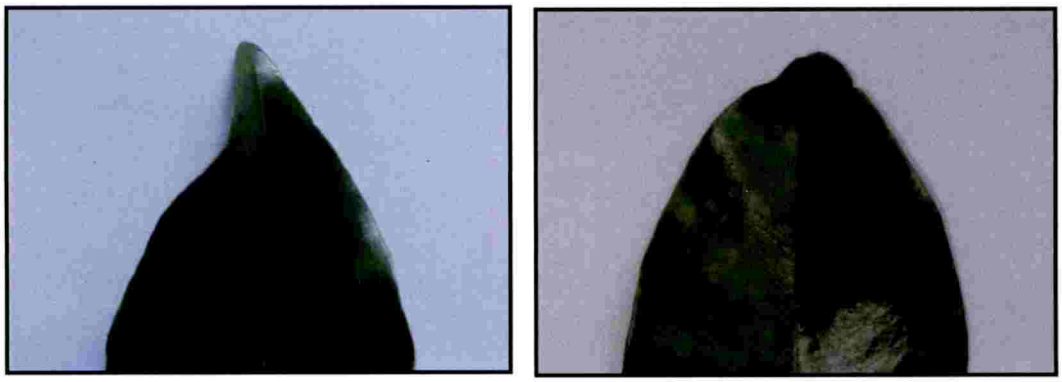
Plate 6. Expressions of colour of mature leaf



Lanceolate

Narrowly elliptic

Plate 7. Expressions of leaf lamina shape



Acuminate **Acute**

Plate 8. Expressions of leaf apex shape

Table 9. Distribution of leaf character among the selected clove accessions

Sl. No.	Character	Expression	Frequency (%)
1	Colour of young leaf	Red Pink with light green tinge	85
		Purple red with light green tinge	5
		Yellow Green with light green tinge	10
2	Colour of mature leaf	Green	35
		Dark Green	65
3	Leaf lamina shape	Lanceolate	85
		Narrowly elliptical	15
4	Leaf apex shape	Acuminate	85
		Acute	15

4.3.1.2.4 Leaf apex shape

Two types of leaf apex shapes namely acuminate and acute were noticed among the twenty selected accessions (Plate 8). Acuminate leaf apex shape (85%) was common compared to acute shape (15%).

4.3.1.3 Bud characters

4.3.1.3.1 Bud forming season

Peak bud forming period was considered as the season of bud forming. Season of bud forming was classified as early, mid and late (Table 10a). In majority of the accessions, mid-season (70%) was predominant. Remaining accessions showed early and late seasons with an equal distribution (15%).The accessions BRC-1, ANC-20, AMC-11 and AMS-13 were early yielders.

4.3.1.3.2 Bud clustering habit

The observation on bud clustering habit revealed that majority of the accessions were showing combination of 1,2,3 flower buds per cluster (85%) and the rest were combination of 1,2,3,4,5 flower buds per cluster (15%). Expressions of bud clustering habit is presented in the plate 9. The accessions BRC1, MRC 5 and MRC 6 had combination of 1,2,3,4,5 flower buds per cluster.

4.3.1.3.3 Bud size

Bud size was measured at bud harvesting period and it was categorized as small, medium and large (Plate 10). Majority of the evaluated accessions had medium sized buds (70%) followed by large (20%) and small (10%).The accessions BLC-16, BRC-3, AMC-11 and AMC-13 had large sized buds.

4.3.1.3.4 Colour of hypanthium

Table 10a. Bud characters of selected clove accessions

Sl. no.	Accessions ID	Bud forming season	Bud clustering habit
1	BRC-1	Early	Combination of 1,2,3,4,5 flower buds per cluster
2	BRC-2	Mid	Combination of 1,2,3 flower buds per cluster
3	BRC-3	Mid	Combination of 1,2,3 flower buds per cluster
4	BRC-4	Mid	Combination of 1,2,3 flower buds per cluster
5	MRC-5	Mid	Combination of 1,2,3,4,5 flower buds per cluster
6	MRC-6	Mid	Combination of 1,2,3,4,5 flower buds per cluster
7	MRC-7	Mid	Combination of 1,2,3 flower buds per cluster
8	MRC-8	Mid	Combination of 1,2,3 flower buds per cluster
9	AMC-9	Late	Combination of 1,2,3 flower buds per cluster
10	AMC-10	Mid	Combination of 1,2,3 flower buds per cluster
11	AMC-11	Mid	Combination of 1,2,3 flower buds per cluster
12	AMC-12	Mid	Combination of 1,2,3 flower buds per cluster
13	AMC-13	Early	Combination of 1,2,3 flower buds per cluster
14	MMC-14	Late	Combination of 1,2,3 flower buds per cluster
15	MMC-15	Mid	Combination of 1,2,3 flower buds per cluster
16	BLC-16	Mid	Combination of 1,2,3 flower buds per cluster
17	BLC-17	Mid	Combination of 1,2,3 flower buds per cluster
18	BLC-18	Late	Combination of 1,2,3 flower buds per cluster
19	MGC-19	Mid	Combination of 1,2,3 flower buds per cluster
20	ANC-20	Early	Combination of 1,2,3 flower buds per cluster

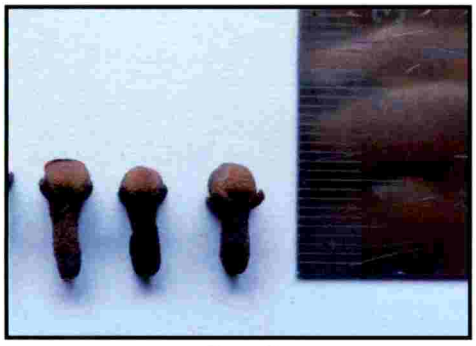
Table 10b. Bud characters of selected clove accessions

Sl. no.	Accessions ID	Bud size	Colour of hypanthium	RHS Colour chart code
1	BRC-1	Medium	Light red pink	37 A
2	BRC-2	Medium	Light red pink	37 A
3	BRC-3	Large	Light red pink	37 A
4	BRC-4	Medium	Light red pink	37 A
5	MRC-5	Medium	Light red pink	37 A
6	MRC-6	Medium	Light red pink	37 A
7	MRC-7	Medium	Light red pink	37 A
8	MRC-8	Medium	Light red pink	37 A
9	AMC-9	Medium	Dark purple red	53 A
10	AMC-10	Medium	Light red pink	37 A
11	AMC-11	Large	Light red pink	37 A
12	AMC-12	Small	Light red pink	37 A
13	AMC-13	Large	Light red pink	37 A
14	MMC-14	Medium	Light red pink	37 A
15	MMC-15	Medium	Light red pink	37 A
16	BLC-16	Large	Light red pink	37 A
17	BLC-17	Medium	Light red pink	37 A
18	BLC-18	Medium	Light red pink	37 A
19	MGC-19	Medium	Light red pink	37 A
20	ANC-20	Small	Light red pink	37 A

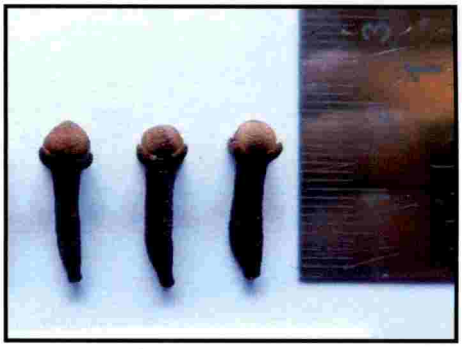
Combination of 1,2,3,4,5 flower buds per cluster

Combination of 1,2,3 flower buds per cluster

Plate 9. Expressions of bud clustering habit



Small



Large

Medium

Plate 10. Expressions of bud size

Dark purple red

Light red pink

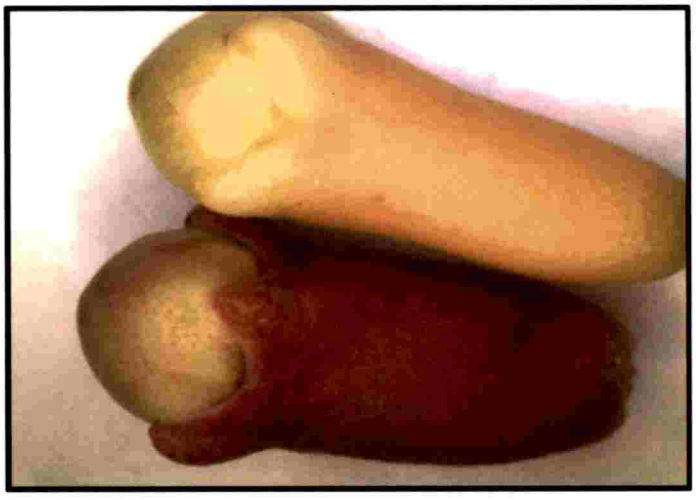


Plate 11. Expressions of colour of hypanthium

Table 11. Distribution of bud characters among selected the clove accession

Sl. No.	Character	Expression	Frequency (%)
1	Bud forming season	Early	15
		Mid	70
		Late	15
2	Bud clustering habit	Combination of 1,2,3,4,5 flower buds per cluster	15
		Combination of 1,2,3 flower buds per cluster	85
3	Bud size	Small	10
		Medium	20
		Large	70
4	Colour of hypanthium	Light red pink	95
		Dark purple red	5

With respect to colour of hypanthium, the predominant hypanthium colour was light red pink (95%) as presented in the plate 11. A unique accession namely AMC-9 exhibited dark purple red representing 5% of the selected accessions.

4.3.1.4 Flower characters

4.3.1.4.1 Petal colour

Majority of the accessions had light green with pinkish tinge colour (95%) followed by green brown in five per cent (Plate 12).

4.3.1.4.2 Sepal colour

Two sepal colour were observed in the selected accessions *viz.* yellow green (95%) and dark purple red in five per cent (Plate 13).

4.3.1.4.3 Colour of stigma

Light green was more common (95%) in the colour of stigma followed by yellow green (5%) and it is represented in plate 14.

4.2.1.5 Fruit and seed characters

4.2.1.5.1 Fruit shape

The shape of the fruit was categorized into oblong and elliptic (Plate 15). In majority of the accessions oblong shape (85%) was predominant and few accessions exhibited elliptic shape (15%). MRC-8, AMC-10 and BLC-17 had elliptical fruit.

4.2.1.5.2 Seed shape

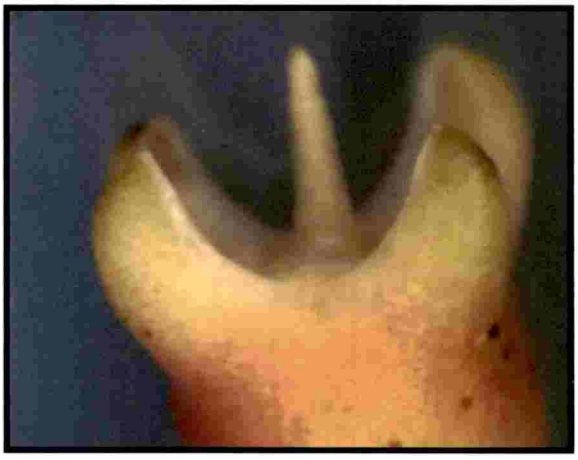
The shape of the seed was categorized into oblong and elliptic (Plate 16). In majority of the accessions oblong shaped seed (85%) was predominant and few accessions exhibited elliptic seed shape (15%).

Table 12. Flower characters of selected clove accessions

Sl. no.	Accessions ID	Position of flower	Petal colour	RHS Colour chart code	Sepal colour	RHS Colour chart code	Colour of stigma	RHS Colour chart code
1	BRC-1	Terminal	Light green with pinkish tinge	149 D	Yellow green	150 C	Light green	145 A
2	BRC-2	Terminal	Light green with pinkish tinge	149 D	Yellow green	150 C	Light green	145 A
3	BRC-3	Terminal	Light green with pinkish tinge	149 D	Yellow green	150 C	Light green	145 A
4	BRC-4	Terminal	Light green with pinkish tinge	149 D	Yellow green	150 C	Light green	145 A
5	MRC-5	Terminal	Light green with pinkish tinge	149 D	Yellow green	150 C	Light green	145 A
6	MRC-6	Terminal	Light green with pinkish tinge	149 D	Yellow green	150 C	Light green	145 A
7	MRC-7	Terminal	Light green with pinkish tinge	149 D	Yellow green	150 C	Light green	145 A
8	MRC-8	Terminal	Light green with pinkish tinge	149 D	Yellow green	150 C	Light green	145 A
9	AMC-9	Terminal	Green brown	152 D	Dark purple red	53 B	Yellow green	154 B
10	AMC-10	Terminal	Light green with pinkish tinge	149 D	Yellow green	150 C	Light green	145 A
11	AMC-11	Terminal	Light green with pinkish tinge	149 D	Yellow green	150 C	Light green	145 A
12	AMC-12	Terminal	Light green with pinkish tinge	149 D	Yellow green	150 C	Light green	145 A
13	AMC-13	Terminal	Light green with pinkish tinge	149 D	Yellow green	150 C	Light green	145 A
14	MMC-14	Terminal	Light green with pinkish tinge	149 D	Yellow green	150 C	Light green	145 A
15	MMC-15	Terminal	Light green with pinkish tinge	149 D	Yellow green	150 C	Light green	145 A
16	BLC-16	Terminal	Light green with pinkish tinge	149 D	Yellow green	150 C	Light green	145 A
17	BLC-17	Terminal	Light green with pinkish tinge	149 D	Yellow green	150 C	Light green	145 A
18	BLC-18	Terminal	Light green with pinkish tinge	149 D	Yellow green	150 C	Light green	145 A
19	MGC-19	Terminal	Light green with pinkish tinge	149 D	Yellow green	150 C	Light green	145 A
20	ANC-20	Terminal	Light green with pinkish tinge	149 D	Yellow green	150 C	Light green	145 A

Green brown (Code: 152 D) Light green with pinkish tinge (Code: 149 D)

Plate 12. Expression of Petal colour

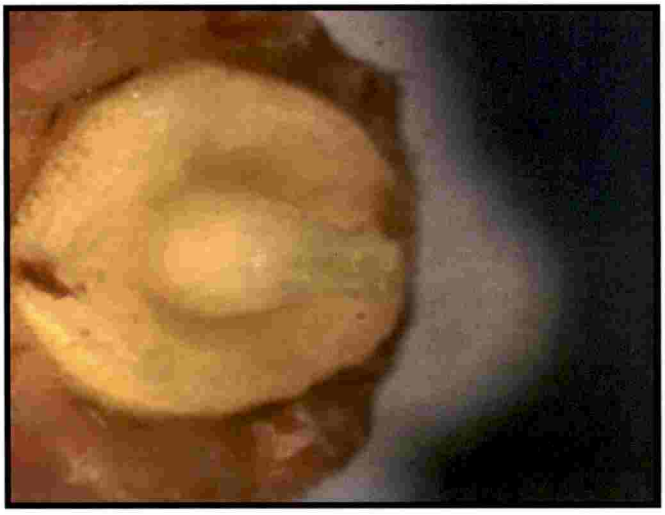


Yellow green (Code: 150 C)

Dark purple red (Code: 53 B)

Plate 13. Expression of sepal colour

Yellow green (Code: 154 B)



Light green (Code: 145 A)

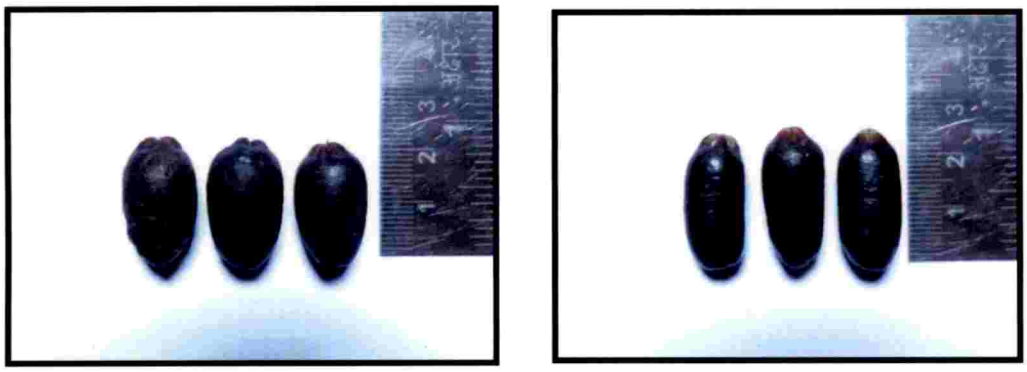
Plate 14. Expressions of stigma colour

Table 13. Distribution of flower characters among the selected clove accessions

Sl. No.	Character	Expression	Frequency (%)
1	Petal colour	Light green with pinkish tinge	95
		Green brown	5
2	Sepal colour	Yellow green	95
		Dark purple green	5
3	Colour of stigma	Light green	95
		Yellow green	5

Table 14. Fruit and seed characters of selected clove accessions

Sl. no.	Accessions ID	Fruit shape	Seed shape
1	BRC-1	Oblong	Oblong
2	BRC-2	Oblong	Oblong
3	BRC-3	Oblong	Oblong
4	BRC-4	Oblong	Oblong
5	MRC-5	Oblong	Oblong
6	MRC-6	Oblong	Oblong
7	MRC-7	Oblong	Oblong
8	MRC-8	Elliptic	Elliptic
9	AMC-9	Oblong	Oblong
10	AMC-10	Elliptic	Elliptic
11	AMC-11	Oblong	Oblong
12	AMC-12	Oblong	Oblong
13	AMC-13	Oblong	Oblong
14	MMC-14	Oblong	Oblong
15	MMC-15	Oblong	Oblong
16	BLC-16	Oblong	Oblong
17	BLC-17	Elliptic	Elliptic
18	BLC-18	Oblong	Oblong
19	MGC-19	Oblong	Oblong
20	ANC-20	Oblong	Oblong



Oblong **Elliptical**

Plate 15. Expression of fruit shape

Oblong **Elliptical**

Plate 16. Expression of seed shape

Table 15. Distribution of fruit and seed character among the selected clove accessions.

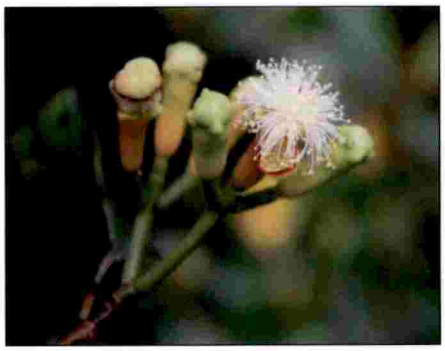
Sl. No.	Character	Expression	Frequency (%)
1	Fruit shape	Elliptical	15
		Oblong	85
2	Seed shape	Elliptical	15
		Oblong	85

Plate 17. Non variable characters among the selected clove accessions

Leaf arrangement

Opposite

Position of flower



Terminal

Colour of peduncle

Green

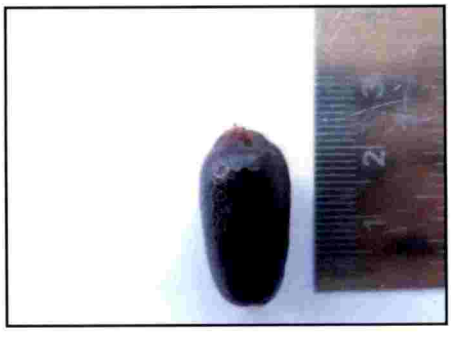
Colour of seed

Green brown (152 A)

Colour of Mature fruit

Dark purple red (53 A)

Colour of ripe fruit



Bluish black

4.3.2 Bivariate analysis of major qualitative characters

Bivariate analysis of major qualitative characters or association of major qualitative characters was done for thirty different association between the characters in clove.

4.3.2.1 Canopy shape vs branching pattern

The association between canopy shape and branching pattern was found to be significant. The branching pattern was not evenly distributed with respect to the canopy shapes. It was observed that when canopy shapes were elliptical majority of the plants were having semi-erect branching pattern (54.54%). Thus, the branching pattern was dependent on the canopy shape.

4.3.2.2 Colour of young leaf vs petal colour

The chi-square statistic was found to be significant between colour of young leaf and petal colour. It was observed that when colour of young leaves were red pink with light green tinge, majority of the accessions were having light green petal (89.47%). Thus, the petal colour was dependent on the colour of young leaves.

4.3.2.3 Colour of young leaf vs sepal colour

The association between colour of young leaf and sepal colour was found to be significant and when colour of young leaves were red pink with light green tinge majority of the accessions were having yellow green sepal (89.47%). Thus, the sepal colour was dependent on the colour of young leaves.

4.3.2.4 Colour of young leaf vs colour of the stigma

For association of colour of young leaf and colour of stigma, the chi-square statistics was found to be significant. When colour of young leaves were red pink with light green tinge, majority of the accessions were having yellow light green stigma (89.47%).

4.3.2.5 Colour of mature leaf vs bud size

The chi-square statistic was found to be significant for association of colour of mature leaf and bud size. Results showed that when bud size was medium 64.29 % of the plants were having dark green leaf. Thus, the bud size was dependent on the colour of mature leaf.

4.3.2.6 Fruit shape vs seed shape

The chi-square statistic revealed significant association between fruit shape and seed shape. The seed shape was evenly distributed with respect to the fruit shape. It was observed that when fruit shape was oblong, the shape of the seed also was oblong. Thus, the fruit shape was fully dependent on the seed shape.

The major association among the quality characters are canopy shape with branching pattern; colour of young leaf with petal colour, sepal colour and colour of stigma; colour of mature leaf with bud size; and fruit shape with seed shape.

Majority of the association of characters viz., canopy shape with bud clustering habit, bud size, fruit shape and seed shape; branching pattern with bud clustering habit, bud size, fruit shape and seed shape; colour of young leaf with bud clustering habit, bud size, fruit shape and seed shape; colour of mature leaf with fruit shape, seed shape, petal colour, sepal colour and colour of stigma; leaf apex shape with bud clustering habit, fruit shape and seed shape; leaf lamina shape with bud clustering habit, fruit shape and seed shape were found to be non significant.

4.3.3 Clustering based on qualitative characters

The investigation will be complete only after thorough statistical investigation into the multifaceted aspects of clove, basically streamlined as qualitative and quantitative characterization.

The qualitative characters namely canopy shape, branching pattern, colour of young leaf, colour of mature leaf, leaf lamina shape, leaf apex shape, bud forming season, bud clustering habit, bud size, colour of hypanthium, petal colour, sepal colour, colour of stigma, fruit shape and seed shape were considered for cluster

Table 16. Canopy shape vs Branching pattern

Canopy shape vs Branching pattern					
		Branching pattern			
		Semi-erect	Irregular	Erect	Total
Canopy shape	Elliptical	6	2	0	8
	Cylindrical	2	0	2	4
	Conical	3	1	0	4
	Pyramidical	0	4	0	4
Total		11	7	2	20
Chi-square statistic		17.662***			

*** denotes significant at 1% level

Table 17. Colour of young leaf vs Petal colour

Colour of young leaf vs Petal colour				
		Petal colour		
		Light green with pinkish tinge	Green brown	Total
Colour of young Leaf	Red pink with light green tinge	17	0	17
	Purple red with light green tinge	0	1	1
	Yellow green with light green tinge	2	0	2
Total		19	1	20
Chi square statistic		20***		

*** denotes significant at 1% level

Table 18. Colour of young leaf vs Sepal colour

Colour of young leaf vs Sepal colour				
		Sepal colour		
		Yellow green	Dark purple red	Total
Colour of young leaf	Red pink with light green tinge	17	0	17
	Purple red with light green tinge	0	1	1
	Yellow green with light green tinge	2	0	2
Total		19	1	20
Chi square statistic	20***			

*** denotes significant at 1% level

Table 19. Colour of young leaf vs Colour of the stigma

Colour of young leaf vs Colour of stigma				
		Colour of stigma		
		Light green	Yellow green	Total
Colour of young leaf	Red pink with light green tinge	17	0	17
	Purple red with light green tinge	0	1	1
	Yellow green with light green tinge	2	0	2
Total		19	1	20
Chi-square statistic	20***			

*** denotes significant at 1% level

Table 20. Colour of mature leaf vs Bud size

Colour of mature leaf vs Bud size					
		Bud size			
		Medium	Large	Small	Total
Colour of mature leaf	Green	5	0	2	7
	Dark green	9	4	0	13
Total		14	4	2	20
Chi-square statistic		5.87*			

*denotes significant at 10% level

Table 21. Fruit shape vs Seed shape

Fruit shape vs Seed shape				
		Seed shape		
		Oblong	Elliptical	Total
Fruit shape	Oblong	17	0	17
	Elliptical	1	2	3
Total		18	2	20
Chi-square statistic	12.59***			

*** denotes significant at 1% level

Table 22. Canopy shape vs Bud clustering habit

Canopy shape vs Bud clustering habit				
		Bud clustering habit		
		Comb.1,2,3,4, 5 buds/cluster	Comb. 1,2,3 buds/cluster	Total
Canopy Shape	Elliptical	1	7	8
	Cylindrical	0	4	4
	Conical	0	4	4
	Pyramidical	2	2	4
Total		3	17	20
Chi-square statistic	NS			

Table 23. Canopy shape vs Bud size

Canopy shape vs Bud size					
		Bud size			
		Medium	Large	Small	Total
Canopy shape	Elliptical	7	0	1	8
	Cylindrical	3	0	1	4
	Conical	2	2	0	4
	Pyramidical	2	2	0	4
Total		14	4	2	20
Chi-square statistic	NS				

Table 24. Canopy shape vs Fruit shape

Canopy shape vs Fruit shape				
		Fruit shape		
		Oblong	Elliptic	Total
Canopy shape	Elliptical	6	2	8
	Cylindrical	4	0	4
	Conical	3	1	4
	Pyramidical	4	0	4
Total		17	3	20
Chi-square statistic	NS			

Table 25. Canopy shape vs Seed shape

Canopy shape vs Seed shape				
		Seed shape		
		Oblong	Elliptic	Total
Canopy shape	Elliptical	6	2	8
	Cylindrical	4	0	4
	Conical	3	1	4
	Pyramidical	4	0	4
Total		17	3	20
Chi-square statistic	NS			

Table 26. Branching pattern vs Bud clustering habit

Branching pattern vs Bud clustering habit				
		Bud clustering habit		
		Combination of 1,2,3,4,5 buds/cluster	Combination of 1,2,3 buds/cluster	Total
Branching pattern	Semi erect	1	10	11
	Irregular	2	5	7
	Erect	0	2	2
Total		3	17	20
Chi square statistic	NS			

Table 27. Branching pattern vs Bud size

Branching pattern vs Bud size					
		Bud size			
		Medium	Large	Small	Total
Branching pattern	Semi erect	9	1	1	11
	Irregular	4	3	0	7
	Erect	1	0	1	2
Total		14	4	2	20
Chi square statistic	NS				

Table 28. Branching pattern vs Fruit shape

Branching pattern vs fruit shape				
		Fruit shape		
		Oblong	Elliptic	Total
Branching pattern	Semi erect	8	3	11
	Irregular	7	0	7
	Erect	2	0	2
Total		17	3	20
Chi- square statistic	NS			

Table 29. Branching pattern vs Seed shape

Branching pattern vs Seed shape				
		Seed shape		
		Oblong	Elliptical	Total
Branching pattern	Semi erect	8	3	11
	Irregular	7	0	7
	Erect	2	0	2
Total		17	3	20
Chi- square statistic	NS			

Table 30. Colour of young leaf vs Bud clustering habit

Colour of young leaf vs Bud clustering habit				
		Bud clustering habit		Total
		Combination of 1,2,3,4,5 buds/cluster	Combination of 1,2,3,4,5 buds/cluster	
Colour of young leaf	Red pink with light green tinge	3	14	17
	Purple red with light green tinge	0	1	1
	Yellow green with light green tinge	0	2	2
Total		3	17	20
Chi-square statistic	NS			

Table 31. Colour of young leaf vs Bud size

Colour of young leaf vs bud size					
		Bud size			
		Medium	Large	Small	Total
Colour of young leaf	Red pink with light green tinge	12	4	1	17
	Purple red with light green tinge	1	0	0	1
	Yellow green with light green tinge	1	0	1	2
Total		14	4	2	20
Chi-square statistic	NS				

Table 32. Colour of young leaf vs Fruit shape

Colour of young leaf vs Fruit shape				
		Fruit shape		
		Oblong	Elliptic	Total
Colour of young leaf	Red pink with light green tinge	13	3	16
	Purple red with light green tinge	1	0	1
	Yellow green with light green tinge	2	0	2
Total		16	3	19
Chi-square statistic	NS			

Table 33. Colour of young leaf vs Seed shape

Colour of young leaf vs Seed shape				
		Seed shape		
		Oblong	Elliptical	Total
Colour of young leaf	Red pink with light green tinge	13	3	16
	Purple red with light green tinge	1	0	1
	Yellow green with light green tinge	2	0	2
Total		16	3	19
Chi-square statistic	NS			

Table 34. Colour of mature leaf vs Fruit shape

Colour of mature leaf vs Fruit shape				
		Fruit shape		
Colour of mature leaf		Oblong	Elliptic	Total
	Green	6	1	7
	Dark green	11	2	13
Total		17	3	20
Chi-square statistic	NS			

Table 35. Colour of mature leaf vs Bud clustering habit

Colour of mature leaf vs Bud clustering habit				
		Bud clustering habit		
Colour of mature leaf		Combination of 1,2,3,4,5 buds/cluster	Combination of 1,2,3, buds/cluster	Total
	Green	1	6	7
	Dark green	2	11	13
Total		3	17	20
Chi-square statistic	NS			

Table 36. Colour of mature leaf vs Seed shape

Colour of mature leaf vs Seed shape				
		Seed shape		
		Oblong	Elliptical	Total
colour mature leaf	Green	6	1	7
	Dark green	11	2	13
Total		17	3	20
Chi-square statistic	NS			

Table 37. Colour of mature leaf vs Petal colour

Colour of mature leaf vs Petal colour				
		Petal colour		
		Light green with pinkish tinge	Green brown	Total
Colour of mature leaf	Green	5	1	6
	Dark green	13	0	13
Total		18	1	19
Chi-square statistic	NS			

Table 38. Colour of mature leaf vs Sepal colour

Colour of mature leaf vs Sepal colour				
		Sepal colour		
		Yellow green	Dark purple red	Total
Colour of mature leaf	Green	5	1	6
	Dark green	13	0	13
Total		18	1	19
Chi-square statistic	NS			

Table 39. Colour of mature leaf vs Colour of stigma

Colour of mature leaf vs Stigma colour				
		Stigma colour		
		Light green	Yellow green	Total
Colour of mature leaf	Green	5	1	6
	Dark green	13	0	13
Total		18	1	19
Chi-square statistic	NS			

Table 40. Leaf apex shape vs Bud clustering habit

Leaf apex shape vs Bud clustering habit				
		Bud clustering habit		
		Combination of 1,2,3,4,5 buds/cluster	Combination of 1,2,3, buds/cluster	Total
Leaf apex shape	Acuminate	3	14	17
	Acute	0	3	3
Total		3	17	20
Chi-square statistic	NS			

Table 41. Leaf apex shape vs Fruit shape

Leaf apex vs Fruit shape				
		Fruit shape		
		Oblong	Elliptic	Total
Leaf apex shape	Acuminate	14	3	17
	Acute	3	0	3
Total		17	3	20
Chi-square statistic	NS			

Table 42. Leaf apex shape vs Seed shape

Leaf apex vs Seed shape				
		Seed shape		
		Oblong	Elliptical	Total
Leaf apex shape	Acuminate	14	3	17
	Acute	3	0	3
Total		17	3	20
Chi-square statistic	NS			

Table 43. Leaf lamina shape vs Bud clustering habit

Leaf lamina shape vs Bud clustering habit				
		Bud clustering habit		
		Combination of 1,2,3,4,5 buds/cluster	Combination of 1,2,3, buds/cluster	Total
Leaf lamina shape	Lanceolate	3	14	17
	Narrowly elliptic	0	3	3
Total		3	17	20
Chi-square statistic	NS			

Table 44. Leaf lamina shape vs Fruit shape

Leaf lamina shape vs Fruit shape				
		Fruit shape		
		Oblong	Elliptic	Total
Leaf lamina shape	Lanceolate	14	3	17
	Narrowly elliptic	3	0	3
Total		17	3	20
Chi-square statistic	NS			

Table 45. Leaf lamina shape vs Seed shape

Leaf lamina shape vs Seed shape				
		Seed shape		
		Oblong	Elliptic	Total
Leaf lamina shape	Lanceolate	14	3	17
	Narrowly elliptic	3	0	3
Total		17	3	20
Chi-square statistic	NS			

analysis using NTSYS (Numerical Taxonomy System) package 2.2. At 80% similarity, 13 cluster were identified (Fig. 1). A detailed list of qualitative characters of the selected accessions and the summary of the qualitative characters based on qualitative clustering are given in table 46.

Cluster analysis was useful in identifying unique group of accessions. Cluster II and VIII has maximum accessions (3) while cluster I, IV, V, VII, IX, X, XI and XIII had only single accessions. In the thirteen clusters identified, cluster II and cluster VIII have two subclusters each. The subcluster in cluster II were II-A and II-B. Sub cluster II-A included accessions BRC-2 and MMC-15. Subcluster II B included BRC-4 alone. In the cluster II all qualitative characters including leaf, bud, flower, fruit and seed characters of BRC-2, MMC-15 and BRC-4 were the same except the tree characters like canopy shape and branching pattern. BRC-2 and MMC-15 had semi erect branching pattern while BRC-5 had irregular branching pattern. The canopy shape of BRC-2 was cylindrical while that of BRC-4 and MMC-15 was elliptical. The cluster VIII consisted of two subclusters VIII-A and VIII-B. MRC-8 and AMC-10 belonged to subcluster VIII-A and BLC-17 to subcluster VIII-B. In cluster VIII, the three accessions MRC-8, AMC-10 as well as BLC-17 had all similar qualitative characters except canopy shape and colour of mature leaf. The accession AMC-9 in cluster XIII showed maximum diversity due to elliptical canopy shape with irregular branching pattern having purple red young leaf and green mature leaf. The bud forming season was late with dark purple red colour for hypanthium and sepal, green brown colour for petal and yellow green colour for stigma.

Cluster VI and XII included two accessions each. MRC-5 and MRC-6 belonged to cluster VI while AMC-11 and AMC-13 belonged to cluster XII. MRC-5 and MRC-6 had pyramidical canopy shape with irregular branching pattern, combination of 1,2,3,4,5 flower buds/cluster with medium bud size with mid bud forming season which made the cluster different from other. AMC-11 and AMC-13 had pyramidical canopy shape with irregular branching pattern, narrowly elliptic leaf lamina shape with early bud forming season producing large bud size.

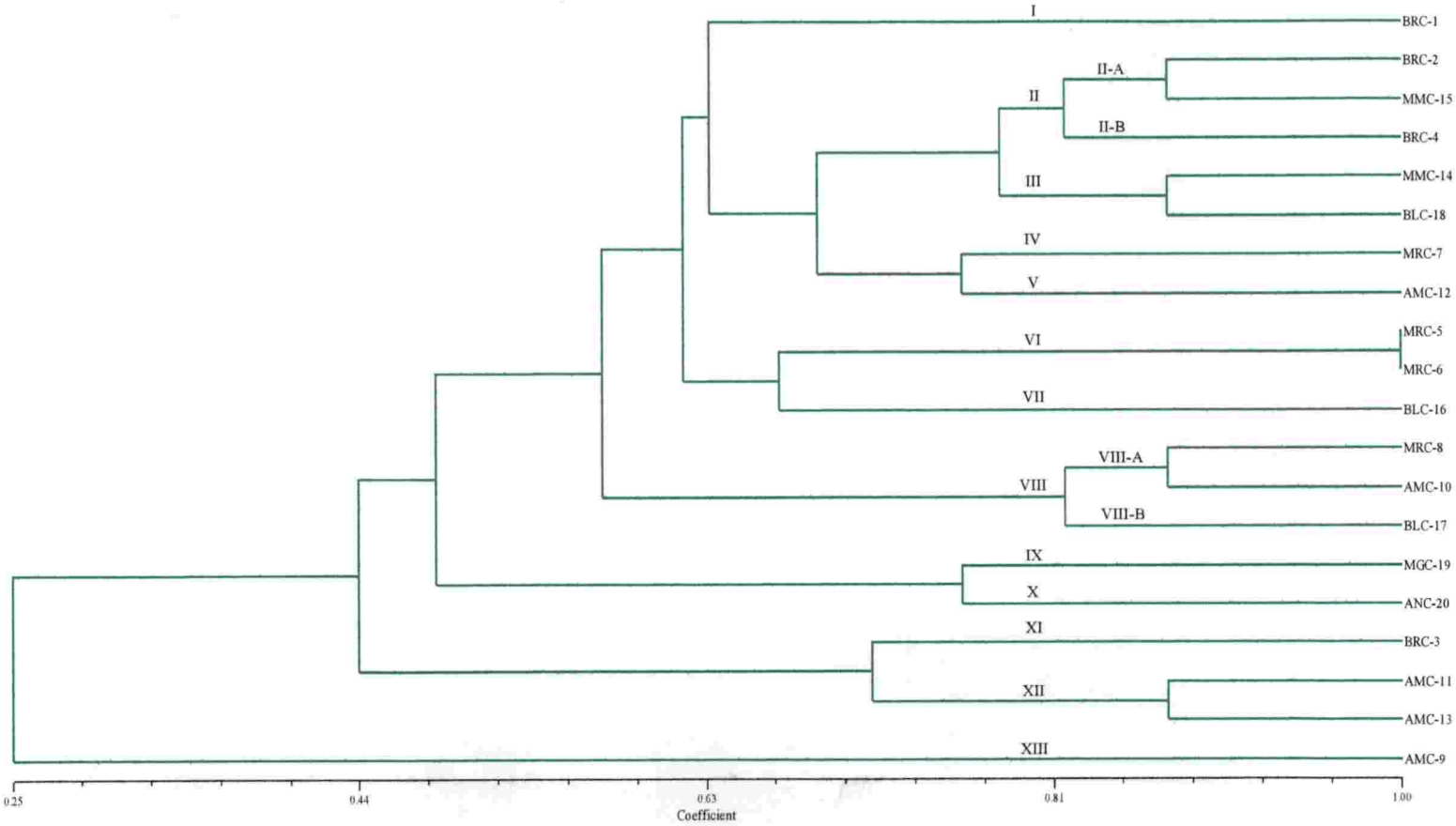


Fig. 1. UPGMA dendrogram of qualitative characteristics of clove accessions

Table 46. Clustering based on qualitative characters in clove accessions

Qualitative cluster	Number of accessions	Cluster members
I	1	BRC-1
II	3	BRC-2, MMC-15, BRC-4
III	2	MMC-14, BLC-18
IV	1	MRC-7
V	1	AMC-12
VI	2	MRC-5, MRC-6
VII	1	BLC-16
VIII	3	MRC-8, AMC-10, BLC-17
IX	1	MGC-19
X	1	ANC-20
XI	1	BRC-3
XII	2	AMC-11, AMC-13
XIII	1	AMC-9

Table 47a. Summary of qualitative characters based on qualitative clustering

Qualitative cluster	Cluster members	Canopy shape	Branching pattern	Colour of young leaf	Colour of mature leaf	Leaf lamina shape	Leaf apex shape
I	BRC-1	Elliptical	Semi-erect	Red pink with light green tinge	Green	Lanceolate	Acuminate
II	BRC-2, MMC-15, BRC-4	Cylindrical/Elliptical	Semi-erect/Irregular	Red pink with light green tinge	Dark green	Lanceolate	Acuminate
III	MMC-14, BLC-18	Elliptical/ Cylindrical	Semi-erect	Red pink with light green tinge	Dark green	Lanceolate	Acuminate
IV	MRC-7	Conical	Semi-erect	Red pink with light green tinge	Green	Lanceolate	Acuminate
V	AMC-12	Elliptical	Semi-erect	Red pink with light green tinge	Green	Lanceolate	Acuminate
VI	MRC-5, MRC-6	Pyramidical	Irregular	Red pink with light green tinge	Dark green	Lanceolate	Acuminate
VII	BLC-16	Conical	Irregular	Red pink with light green tinge	Dark green	Lanceolate	Acuminate
VIII	MRC-8, AMC-10, BLC-17	Elliptical/Conical	Semi-erect	Red pink with light green tinge	Dark green /Green	Lanceolate	Acuminate
IX	MGC-19	Cylindrical	Erect	Yellow green with light green tinge	Green	Lanceolate	Acuminate
X	ANC-20	Cylindrical	Erect	Yellow green with light green tinge	Green	Lanceolate	Acuminate
XI	BRC-3	Conical	Semi-erect	Red pink with light green tinge	Dark green	Narrowly elliptic	Acute
XII	AMC-11, AMC-13	Pyramidical	Irregular	Red pink with light green tinge	Dark green	Narrowly elliptic	Acute
XIII	AMC-9	Elliptical	Irregular	Purple red with light green tinge	Green	Lanceolate	Acuminate

Table 47b. Summary of qualitative characters based on qualitative clustering (continued)

Qualitative cluster	Cluster members	Bud forming season	Bud clustering habit	Bud size	Colour of hypanthium
I	BRC-1	Early	Combination of 1,2,3,4,5 flower buds /cluster	Medium	Light red pink
II	BRC-2, MMC-15, BRC-4	Mid	Combination of 1,2,3 flower buds /cluster	Medium	Light red pink
III	MMC-14, BLC-18	Late	Combination of 1,2,3 flower buds /cluster	Medium	Light red pink
IV	MRC-7	Mid	Combination of 1,2,3 flower buds /cluster	Medium	Light red pink
V	AMC-12	Mid	Combination of 1,2,3 flower buds /cluster	Small	Light red pink
VI	MRC-5, MRC-6	Mid	Combination of 1,2,3,4,5 flower buds /cluster	Medium	Light red pink
VII	BLC-16	Mid	Combination of 1,2,3 flower buds /cluster	Large	Light red pink
VIII	MRC-8, AMC-10, BLC-17	Mid	Combination of 1,2,3 flower buds /cluster	Medium	Light red pink
IX	MGC-19	Mid	Combination of 1,2,3 flower buds /cluster	Medium	Light red pink
X	ANC-20	Early	Combination of 1,2,3 flower buds /cluster	Small	Light red pink
XI	BRC-3	Mid	Combination of 1,2,3 flower buds /cluster	Large	Light red pink
XII	AMC-11, AMC-13	Early	Combination of 1,2,3 flower buds /cluster	Large	Light red pink
XIII	AMC-9	Late	Combination of 1,2,3 flower buds /cluster	Medium	Dark purple red

Table 47c. Summary of qualitative characters based on qualitative clustering (continued)

Qualitative cluster	Cluster members	Petal colour	Sepal colour	Colour of stigma	Fruit shape	Seed shape
I	BRC-1	Light green with pinkish tinge	Yellow green	Light green	Oblong	Oblong
II	BRC-2, MMC-15, BRC-4	Light green with pinkish tinge	Yellow green	Light green	Oblong	Oblong
III	MMC-14, BLC-18	Light green with pinkish tinge	Yellow green	Light green	Oblong	Oblong
IV	MRC-7	Light green with pinkish tinge	Yellow green	Light green	Oblong	Oblong
V	AMC-12	Light green with pinkish tinge	Yellow green	Light green	Oblong	Oblong
VI	MRC-5, MRC-6	Light green with pinkish tinge	Yellow green	Light green	Oblong	Oblong
VII	BLC-16	Light green with pinkish tinge	Yellow green	Light green	Oblong	Oblong
VIII	MRC-8, AMC-10, BLC-17	Light green with pinkish tinge	Yellow green	Light green	Elliptical	Elliptical
IX	MGC-19	Light green with pinkish tinge	Yellow green	Light green	Oblong	Oblong
X	ANC-20	Light green with pinkish tinge	Yellow green	Light green	Oblong	Oblong
XI	BRC-3	Light green with pinkish tinge	Yellow green	Light green	Oblong	Oblong
XII	AMC-11, AMC-13	Light green with pinkish tinge	Yellow green	Light green	Oblong	Oblong
XIII	AMC-9	Green brown	Dark purple red	Yellow green	Oblong	Oblong

4.3.4 Quantitative characters

4.3.4.1 Tree characters

4.3.4.1.1 Plant height

The plant height ranged from 5.15 m to 15.25 m. (Table 48). Accession AMC-13 had the lowest height (5.15m) followed by MMC-14. The highest plant among the accessions was BLC-18. In accessions with pyramidal canopy the plant height ranged from 6.50 to 7.35m while for conical shape the plant height ranged from 7.35 m to 13.6m.

4.3.4.1 Girth at 45 cm height

The girth at 45 cm height ranged from 44.10 cm to 138.10 cm. The girth at 45 cm was the highest for BRC-3 (138.1cm) and lowest for ANC-20.

4.3.4.1.3 Canopy spread

The canopy spread N-S ranged from 3.1 m to 7.42 m and canopy spread E-W ranged from 2.95 m to 7.9 m. The N-S spread was the highest for MRC-7 and lowest for ANC-20. The E-W canopy spread was the highest for AMC-11 and lowest for ANC-20 (2.95m)

4.3.4.1.4 Number of branches

The number of branches ranged from 26 to 55. AMC-20 showed maximum number of branches.

4.3.4.2 Leaf characters

The leaf length ranged from 9.66 cm in ANC- 20 to 13.93 cm in MRC-5, leaf breadth ranged from 3.55 cm to 4.72 cm and leaf area ranged from 23.07 cm in ANC-20 to 42.93 cm in AMC-11.

Table 48. Tree characters of selected clove accessions

Sl. no.	Accession	Plant height (m)	Girth at 45 cm	Canopy spread (m)		Number of branches
				N-S	E-W	
1	BRC-1	9.20	118.5	4.20	3.75	48
2	BRC-2	9.7	67.33	4.55	4.1	40
3	BRC-3	13.6	138.1	4.60	4.35	44
4	BRC-4	6.45	86.2	4.95	5.10	38
5	MRC-5	6.55	85.4	5.15	4.30	46
6	MRC-6	7.35	96	4.80	4.75	39
7	MRC-7	14.95	99.8	7.42	7.05	47
8	MRC-8	9.7	90.1	5.90	6.20	38
9	AMC-9	5.6	53	3.25	2.90	31
10	AMC-10	7.35	76.55	4.23	3.65	49
11	AMC-11	6.85	102.5	6.25	7.90	55
12	AMC-12	6.50	85.9	4.30	4.00	38
13	AMC-13	5.15	68.2	3.45	3.55	41
14	MMC-14	5.30	69	4.35	3.90	48
15	MMC-15	7.85	82.9	5.05	5.8	43
16	BLC-16	10.30	92.5	5.0	5.8	44
17	BLC-17	5.9	65.8	4.25	4.05	36
18	BLC-18	15.25	97.3	4.10	4.30	33
19	MGC-19	7.15	55.3	3.15	3.40	31
20	ANC-20	6.80	44.1	3.1	2.95	26

Table 49. Leaf characters of selected clove accessions

Sl. no.	Accession	Leaf length (cm)	Leaf breadth (cm)	Leaf area (cm^2)
1	BRC-1	10.98	4.29	31.37
2	BRC-2	10.91	4.02	28.08
3	BRC-3	13.77	4.62	39.31
4	BRC-4	11.79	4.43	32.12
5	MRC-5	13.93	4.21	39.81
6	MRC-6	11.2	4.02	30.8
7	MRC-7	10.1	3.8	28.08
8	MRC-8	12.18	4.1	35.73
9	AMC-9	12.27	4.39	35.17
10	AMC-10	10.57	3.94	28.87
11	AMC-11	13.91	4.72	42.93
12	AMC-12	10.04	3.78	29.25
13	AMC-13	13.44	4.07	38.63
14	MMC-14	11.95	4.26	33.64
15	MMC-15	12.29	4.42	35.61
16	BLC-16	13.09	4.07	37.42
17	BLC-17	13.27	4.05	38.35
18	BLC-18	10.4	3.73	30.86
19	MGC-19	12.61	4.51	37.49
20	ANC-20	9.66	3.55	23.07

4.3.4.3 Bud, flower, fruit and seed characters

The bud character include number of inflorescence/m2, number of flower buds /inflorescence, single bud weight (fresh), single bud weight (dry), mature bud length, mature bud diameter, period from bud initiation to bud harvest, bud yield per tree (fresh) and bud yield per tree (dry).

The number of inflorescence /m^2 was the highest in AMC-12 (155.5) and lowest in ANC-20 (36.25). The number of flower buds /inflorescence ranged from 6.08 to 18.21. The single bud weight (fresh), single bud weight (dry) was the highest for BRC-3. The single bud weight (dry) ranged from 66.5 to 128.5 g. Higher values for single bud weight (dry) was noted in accessions like BRC-3 (128.5 mg), MRC-8 (120 mg), BRC-1 (114 mg), MRC-7 (110 mg), BLC-18 (108 mg) and MRC-5 (101.5 mg).

The mature bud length varied from 14.94 mm to 19.06 mm while the mature bud diameter ranged from 4.9 mm in AMC-9 to 6.41 mm in BRC-3. The period taken from bud initiation to bud harvest ranged from 103.8 to 118.4 days.

The pooled mean of fresh bud yield per tree varied from 2.7 to 40.25 kg. AMC-9 and ANC-20 were lower yielders. However, BRC-1, MRC-5, MRC-6, MRC-8, AMC-10 and MMC-15 were good yielders yielding more than 30 kg/tree as revealed from pooled mean. The bud weight per tree dry was the highest for MRC-6 (12.25kg/tree) followed by MRC-5 (12.2 kg/tree). Most of the accessions showed biennial nature, while the yield gap was less in accessions like AMC-12 and BLC-16.

The length of flower ranged from 14.24 mm to 21.84 mm and the breadth ranged from 9.85 mm to 14.82 mm. The number of sepal and petal was constant while the length of sepal ranged from 2.49 mm to 3.3 mm and length of petal ranged from 4.91 to 6.3 mm.

The fruit weight ranged from 1.2 g in ANC-20 to 3.53 g in BRC-3. The ratio of fruit to seed ranged from 2.37 to 3.64. The highest seed length corresponded to

Table 50. Flower characters of selected clove accessions

Sl. no.	Accession	Length of flower (mm)	Breadth of flower (mm)	Number of petal	Number of sepal	Length of petal (mm)	Length of sepal (mm)
1	BRC-1	21.38	12.39	4	4	5.75	3.3
2	BRC-2	17.19	11.23	4	4	5.43	2.93
3	BRC-3	19.92	14.82	4	4	6.13	2.76
4	BRC-4	21.74	13.08	4	4	5.71	3.15
5	MRC-5	21.84	12.46	4	4	5.21	2.95
6	MRC-6	21.17	13.3	4	4	5.43	2.86
7	MRC-7	20.98	12.39	4	4	5.8	3.08
8	MRC-8	21.49	11.88	4	4	5.55	3.01
9	AMC-9	17.96	10.89	4	4	5.39	2.55
10	AMC-10	20.5	11.89	4	4	5.45	2.51
11	AMC-11	19.8	14.81	4	4	6.3	2.84
12	AMC-12	14.24	12.62	4	4	5.14	2.93
13	AMC-13	19.71	14.81	4	4	5.99	2.89
14	MMC-14	21.32	12.75	4	4	5.8	3.08
15	MMC-15	20.98	12.1	4	4	5.61	3.01
16	BLC-16	19.47	14.74	4	4	6.13	2.76
17	BLC-17	21.47	12.3	4	4	5.76	2.96
18	BLC-18	19.51	12.9	4	4	5.28	2.89
19	MGC-19	17.19	10.76	4	4	5.06	2.61
20	ANC-20	16.36	9.85	4	4	4.91	2.49

Table 51a. Bud characters of selected clove accessions

Sl. no.	Accession	Number of inflorescence/m^2	Number of flower buds/ inflorescence	Single bud weight (fresh) (mg)	Single bud weight (dry) (mg)	Mature bud length (mm)	Mature bud diameter (mm)
1	BRC-1	114	13.47	327.05	114	19.06	5.94
2	BRC-2	71	11.42	243.6	73	15.85	5.2
3	BRC-3	73.75	8.47	400.37	128.5	17.73	6.41
4	BRC-4	79.5	12.31	310.59	103	18.56	5.79
5	MRC-5	70.25	15.05	367.47	101.5	18.76	5.83
6	MRC-6	97.5	18.21	334.2	91.6	18.04	5.83
7	MRC-7	43.5	10.47	324.48	110	18.73	5.55
8	MRC-8	51	11.42	314.43	120	18.53	5.1
9	AMC-9	48.5	7.47	237.04	76	15.99	4.9
10	AMC-10	114.25	9.31	305.58	81	18.38	5.32
11	AMC-11	87.75	7.1	358.3	99	18.03	6.2
12	AMC-12	155.5	9	253.96	75.5	15.26	5.18
13	AMC-13	99.5	9.57	337.59	89.5	18.18	6.13
14	MMC-14	113	10.47	326.32	92.5	17.89	5.39
15	MMC-15	79.5	12.1	332.35	94	17.97	5.9
16	BLC-16	69	7.47	348.5	108	17.94	6.04
17	BLC-17	100.5	12	330.5	94.5	18.87	4.97
18	BLC-18	85	10.94	281	80	16.25	5.18
19	MGC-19	24.75	6.68	274.53	82	15.68	5.19
20	ANC-20	36.25	6.05	216.27	66.5	14.94	4.92

Table 51b. Bud characters of selected clove accessions

Sl. no.	Accession	Period from bud initiation to bud harvest (days)	Fresh bud yield per tree (Kg)			Dry bud yield per tree (Kg)		
			2016-17	2017-18	Pooled mean	2016-17	2017-18	Pooled mean
1	BRC-1	112.4	60.5	20	40.25	17.7	5.9	11.8
2	BRC-2	106.2	21.5	10.2	15.85	7.4	3.5	5.45
3	BRC-3	110	23	11	17	7.1	3.4	5.25
4	BRC-4	109.2	33.5	24.25	28.87	12.4	9	10.7
5	MRC-5	104.2	17	49	33	6.3	18.1	12.2
6	MRC-6	113	27	46.5	36.75	9	15.5	12.25
7	MRC-7	106.2	29.5	8	18.75	8.9	2.5	5.7
8	MRC-8	106.2	24	41.5	32.75	7.3	12.6	9.95
9	AMC-9	116.2	10	6.5	8.25	2.7	1.8	2.25
10	AMC-10	118.4	28	35.2	31.6	8.7	11	9.85
11	AMC-11	114.2	24	14.5	19.25	9.2	5.6	7.4
12	AMC-12	115.4	29	24	26.5	10.7	8.88	9.8
13	AMC-13	115.4	22.5	16.25	19.37	7.75	5.6	6.6
14	MMC-14	107.4	35	24.7	29.85	13.5	9.5	11.5
15	MMC-15	108.8	34.5	25.8	30.15	12.3	9.2	10.75
16	BLC-16	106.6	28.5	26.3	27.4	9.2	8.5	8.85
17	BLC-17	103.8	27	18.5	22.75	9.6	6.6	8.1
18	BLC-18	106	24	14.5	19.25	8.6	5.2	6.9
19	MGC-19	106.8	12	8	10	4.13	2.75	3.44
20	ANC-20	111	5.2	2.6	3.9	1.73	0.86	1.29

Table 52. Fruit and seed characters of selected clove accessions

Sl. no.	Accession	Fruit weight (fresh) (g)	Ratio of fruit to seed	Seed length (mm)	Seed breadth (mm)	Seed weight (g)	Time taken for harvest of fruits from flowering (Days)
1	BRC-1	2.77	2.72	18.78	8.43	1.01	88.2
2	BRC-2	2.34	2.68	16.98	7.99	0.87	93.3
3	BRC-3	3.53	2.97	19.31	9.19	1.18	90.4
4	BRC-4	2.61	2.73	17.8	8.7	0.95	92.2
5	MRC-5	2.45	2.61	17.76	8.53	0.93	94.7
6	MRC-6	2.45	2.37	17.29	8.35	1.03	92.9
7	MRC-7	2.02	2.86	16.34	7.68	0.7	93.8
8	MRC-8	2.63	3.09	18.26	7.55	0.85	94.1
9	AMC-9	2.33	3.64	16.38	8.06	0.64	96.5
10	AMC-10	2.03	3.03	16.65	7.52	0.67	97.4
11	AMC-11	3.32	3.01	18.92	8.93	1.1	95.3
12	AMC-12	1.23	2.5	13.95	6.28	0.49	96.9
13	AMC-13	3.09	3.13	18.91	8.92	0.98	86.8
14	MMC-14	2.52	2.41	17.63	8.43	1.04	96.9
15	MMC-15	2.6	2.65	18.07	8.7	0.98	96
16	BLC-16	3.13	2.91	18.91	8.69	1.07	89
17	BLC-17	2.46	2.9	18.31	7.52	0.84	90.4
18	BLC-18	2.1	2.67	16.84	7.8	0.78	96.5
19	MGC-19	1.89	2.67	16	7.65	0.71	97.6
20	ANC-20	1.2	2.64	13.2	6.11	0.45	87.8

Table 53. Quality parameters of selected clove accessions

Sl. no.	Accession	Volatile oil (%)		Oleoresin (%)		Eugenol content of the bud (%)
		Bud oil	Stem oil	Bud oleoresin	Stem oleoresin	
1	BRC-1	19.6	5.1	24.3	9.8	59.35
2	BRC-2	13.33	5.8	20.5	9	57.89
3	BRC-3	13.2	5.2	21.1	10.1	61.43
4	BRC-4	16.66	6.33	23	12.2	70.52
5	MRC-5	16	5.1	20.4	8.2	62.52
6	MRC-6	18.66	5.6	22.8	8.8	62.36
7	MRC-7	18.13	5	23.2	8	62.76
8	MRC-8	17.6	3.6	20.1	7.1	54.29
9	AMC-9	14	4.85	19.2	8.5	69.6
10	AMC-10	15.12	6.26	21.5	9.6	55.05
11	AMC-11	15.68	7.2	19.9	11.6	62.9
12	AMC-12	13.48	7	18.5	10.2	70.58
13	AMC-13	16.53	4.53	21.7	7.9	61.84
14	MMC-14	14.20	4.4	19	8.3	57.39
15	MMC-15	13.6	4.7	18.2	7.5	58.71
16	BLC-16	14.66	6.7	20.66	10.3	58.27
17	BLC-17	12.53	6.1	16.9	9.5	70.77
18	BLC-18	15.6	5.9	22.7	9.1	57.18
19	MGC-19	14.8	5.5	19.5	8.8	69
20	ANC-20	13.71	5.8	20.2	10	69.61

highest fruit length and was noted in BRC-3. The seed length varied from 13.2 to 19.31 mm and seed breadth from 6.11 to 9.19 mm in the selected accessions. The seed weight was the highest for BRC-3 (1.18 g) followed by 1.1 g in AMC-11. The time taken for harvest of fruits from flowering ranged from 86.8 to 97.6 days.

4.3.4.4 Quality parameters

The bud oil varied from 12.53% to 19.6%, while the stem oil ranged from 3.6 to 7.2 % in the selected accessions. Highest yield of bud oil and oleoresin was obtained from BRC-1. The bud oleoresin showed a range from 16.9 to 24.3 % and the stem oleoresin from 7.1 to 12.2%. The eugenol content between accessions ranged between 54.29 and 70.77%. The highest eugenol content was obtained from BLC-17 (Table no.53)

The mean number of inflorescence/m^2 to be 80.7 with standard deviation of 31.43 (Table 54). Higher the standard deviation higher is the variability as revealed from the wide range of inflorescence (24.75 to 155.5). The number of flower buds/inflorescence ranged from 6.05 to 18.21 with a mean of 10.45 and standard deviation 3. The character single bud weight (fresh) recorded a higher value of 400.37 mg and a lower value of 216.27 mg with a standard deviation of 47.06. The ultimate economic end point, single bud weight (dry) ranged from 66.5 to 128.5 with mean 94.01 and standard deviation 16.67. The mean mature bud length was 17.53 mm and the standard deviation was 1.32. For mature bud diameter, the minimum was 4.9 mm and the maximum value was 6.41 mm with a standard deviation of 0.46. The standard deviation with respect to the period from bud initiation to bud harvest was 4.36 and the values ranged between 103.8 and 118.4. The bud yield per tree (fresh) showed a standard deviation of 10 and it ranged from 40.25 to 3.9. while the bud weight (dry) showed a standard deviation of 3.34. The standard deviation for length and breadth of flower was 2.09 and 1.4 respectively. The mean length of petal was 5.59 and that of sepal was 2.88. The standard deviation for fresh fruit weight and seed weight was 0.6 and 0.2 respectively. The ratio of fruit to seed ranged from 2.37 to 3.64 with a standard deviation of 0.29.

Table 54. Descriptive statistics for bud, flower, fruit and seed characters

Characters	Mean	Standard Deviation	Minimum	Maximum
Number of inflorescence/m^2	80.7	31.43	24.75	155.5
Number of flower buds/inflorescence	10.45	3	6.05	18.21
Single bud weight (fresh)(g)	311.21	47.06	216.27	400.37
Single bud weight (dry)(g)	94.01	16.67	66.5	128.5
Mature bud length(mm)	17.53	1.32	14.94	19.06
Mature bud diameter(mm)	5.55	0.46	4.9	6.41
Period from bud initiation to bud harvest(days)	109.87	4.36	103.8	118.4
Bud yield per tree (fresh)(Kg/tree)	24.38	10	3.9	40.25
Bud yield per tree (dry)(Kg/tree)	8.27	3.34	1.29	12.25
Length of flower (mm)	19.71	2.09	14.24	21.84
Breadth of flower(mm)	12.60	1.40	9.85	14.82
Length of petal(mm)	5.59	0.37	4.91	6.3
Length of sepal(mm)	2.88	0.21	2.49	3.3
Fruit weight fresh(g)	2.44	0.60	1.2	3.53
Ratio of fruit to seed	2.81	0.29	2.37	3.64
Seed length(mm)	17.32	1.61	13.2	19.31
Seed breadth(mm)	8.05	0.81	6.11	9.19
Seed weight(g)	0.86	0.20	0.45	1.18
Time taken for harvest of fruit from flowering (days)	93.34	3.48	86.8	97.6

The minimum time taken for harvest of fruit from flowering was 86.8 and the maximum time taken was 97.6 and the standard deviation noted was 3.48.

4.3.4.4.1 Quality analysis

The quality analysis were carried based on the quality parameters namely bud oil, bud oleoresin, clove stem oil, clove stem oleoresin, eugenol content of the bud and GC profiling of elite accessions. The quality parameters were summarized based on descriptive statistics (Table 55).

An average bud oil content among the selected accessions was 15.35% with standard deviation of 1.99. The bud oil per cent ranged from 12.53 to 19.6%. The stem oil ranged from 3.6 to 7.2% with a mean of 5.53% and standard deviation 0.91. An average bud oleoresin was found to be 20.66% with standard deviation of 1.89. The bud oleoresin ranged from 16.9 to 24.3%. The stem oleoresin ranged from 7.11 to 12.2% with mean of 9.22% and standard deviation 1.3. The main component in the clove essential oil is eugenol and it showed wide ranging between 54.29 to 70.77%. with standard deviation 5.54 and mean of 62.6%. Maximum standard deviation was seen in eugenol content between accessions in the quality parameters studied.

4.3.4.4.1 GC MS profile of bud oil of selected clove accessions

GC MS analysis of the bud oils of the elite clove accessions like BRC-1, BRC-3, MRC-5 and MRC-6 exhibited 25 constituents. The major constituents of the bud oil were p-eugenol, eugenyl acetate, β-caryophyllene, 1,4-Diethyl-2-methyldecahydro-4-quinolinol, β-cubebene and α-humulene. There was no much considerable variation among oil constituents of the elite clove accessions. Chemo profiling data of the bud volatile of the selected clove accessions are presented in table 56 and the chromatogram in the appendix III

The major component of clove bud oil is eugenol and it ranged from 59.36 to 62.53% among the selected elite clove accessions. An average eugenyl acetate

Table 55. Descriptive statistics of the quality parameter

Quality characters	Mean (%)	Standard deviation	Minimum (%)	Maximum (%)
Bud oil	15.3545	1.99199	12.53	19.6
Stem oil	5.5335	0.91816	3.6	7.2
Bud oleoresin	20.668	1.89433	16.9	24.3
Stem oleoresin	9.225	1.30015	7.1	12.2
Eugenol	62.601	5.54213	54.29	70.77

Table 56. GC MS profile of bud oil of selected clove accessions

Constituents	BRC-1 (%)	BRC-3 (%)	MRC-5 (%)	MRC-6 (%)
4,8,8-Trimethyl-2-methylene-4-vinylbicyclo[5.2.0]nonane	*	*	*	*
Chavicol	*	*	*	*
β-Cubebene	0.951	1.352	1.389	1.385
Germacrene D	*	*	*	*
p-Eugenol	59.356	61.439	62.526	62.361
Farnesene	*	*	0.059	0.080
β-Caryophyllene	6.540	8.871	8.331	8.896
β-Ylangene	0.115	0.165	0.162	0.163
α-Humulene	0.827	1.088	1.084	1.109
β-Clovene	0.098	0.030	0.030	0.024
β-Cadinin	0.124	0.106	0.155	0.148
β-Cedrene	0.366	0.735	0.624	0.572
ĩ-Cadinene	0.043	0.030	0.029	0.031
1-Ethyl-1H-pyrrole-2-carbaldehyde	*	*	*	*
δ-Cadinene	0.619	0.592	0.806	0.818
Eugenyl acetate	23.046	19.647	21.223	21.229
β-Selinene	0.102	0.136	0.104	0.107
6-Isopropenyl-4,8a-dimethyldecahydro-1-naphthalenol	0.031	0.032	0.028	0.033
S-Neoclovene	0.118	0.109	0.154	0.143
(+)-Aromadendrene	0.042	0.035	0.042	0.040
Torreyol	0.091	0.070	0.087	0.075
1,4-Diethyl-2-methyldecahydro-4-quinolinol	3.378	2.938	0.642	0.557
Total content of constituents	95.900	97.400	97.500	97.800

*denotes not detected

was found to be 21.29% and ranged from 19.64 to 23.04%. β-Caryophyllene ranged from 6.54 to 8.896% with mean of 8.16%. 1,4-Diethyl-2-methyldecahydro-4-quinolinol ranged from 0.55% to 3.37%.

β-Cubebene ranged from 0.83 to 1.11% with mean of 1.03% and an average α-humulene was found to be 0.96% and ranged from 0.82 to 1.1%.

4.3.5 Incidence of diseases

In clove, leaf spot and die back of the branches were the most common and serious diseases. During the *in situ* evaluation leaf spot disease was noticed in the selected clove accessions.

4.3.6 Incidence of pests

There was no pest incidence report in the selected clove accessions.

4.3.7 Quantitative characterization

A multivariate analysis of the quantitative characters viz.; plant height, girth at 45 cm height, canopy spread (N-S), canopy spread (E-W), number of branches, leaf length, leaf breadth, leaf area, number of inflorescence/m^2, number of flower buds/ inflorescence, length of flower, breadth of flower, length of petal, length of sepal, single bud weight (fresh), single bud weight (dry), mature bud length, mature bud diameter, period from bud initiation to bud harvest, fresh bud yield per tree, dry bud yield per tree, fresh fruit weight, ratio of fruit to seed, seed length, seed breadth, seed weight, time taken for harvest of fruit from flowering, bud oil, bud oleoresin, clove stem oil, clove stem oleoresin and eugenol were carried out. As only single trees were spotted in the detailed investigation, the clustering of the accessions based on quantitative characters were carried out using Principal Component Analysis.

The Principal Component Analysis resulted in the first two principal component explaining 88.8% variation (Appendix IV). The eigen vectors

Table 57. Component loadings for the first two Principal Components

Variables	Principal Component 1	Principal Component 2
Plant height	0.013	0.03
Girth at 45 cm height	**0.335**	-0.044
Canopy spread (N-S)	0.01	0.007
Canopy spread (E-W)	0.012	0.01
Number of branches	0.099	-0.05
Leaf length	0.015	0.014
Leaf breadth	0.003	0.003
Leaf area	0.054	0.034
Number of inflorescence/m^2	0.172	**-0.959**
Number of flower buds/inflorescence	0.021	-0.021
Length of flower	0.027	0.012
Breadth of flower	0.021	-0.007
Length of petal	0.005	0.001
Length of sepal	0.002	-0.002
Single bud weight (fresh)	**0.87**	0.174
Single bud weight (dry)	**0.262**	0.163
Mature bud length	0.02	0.002
Mature bud diameter	0.007	0.001
Period from bud initiation to bud harvest	-0.01	-0.065
Bud yield per tree (fresh)	0.114	-0.101
Bud yield per tree (dry)	0.038	-0.04
Fruit weight (fresh)	0.009	0.004
Ratio of fruit to seed	0	0.003
Seed length	0.024	0.007
Seed breadth	0.011	0.005
Seed weight	0.003	0.001
Time taken for harvest of fruit from flowering	-0.013	-0.014
Bud oil	0.012	0.004
Bud oleoresin	0.008	0.003
Clove stem oil	-0.001	-0.01
Clove stem oleoresin	0.002	-0.009
Eugenol content of bud	-0.04	0.003

designated as Principal Component-1 and Principal Component-2 with the respective component loadings of the 32 characters are given in the table 57. A score plot was generated based on the first two Principal Components using Minitab version 18. The score plot is given in the figure 2. Fourteen clusters were identified based on score plot. The said clusters earmarked in the same figure. The listing of the constituent members of the 14 quantitative clusters are given in the table 58.

4.3.7.1 Parallelism between qualitative and quantitative clustering

The distribution of individual members in qualitative cluster over the 14 exclusive quantitative clusters is given in the table 58. The parallelism between qualitative and quantitative clustering resulted in the generation of intuitive perceived quantitative characterization. The perceived quantitative characters are given in table 59 to 61d.

The perceived quantitative characterization speaks of the extent to which one can conceive the quantitative characters of clove based on an easily identifiable qualitative character.

4.3.7.2 Linkage between major quantitative characters of clove

The linkage was analysed based on the biplot of Principal Component scores of the characters. This biplot is justifiable by the fact that the first two principal component explained 88.8% of variation. The biplot revealed that the characters C2, C5, C9, C 15, C16 and C20 (C2-Girth at 45 cm height, C5-Number of branches, C9-Number of inflorescence/m^2, C15-Single bud weight (fresh), C16-Single bud weight (dry) and fresh bud yield per tree) were the major characters. Among these the major independent character was C9 (number of inflorescence per m^2). C9 and C15 are independent characters. Thus, the single bud weight (fresh) is independent of the inflorescence number. C2, C15 and C16 are associated to a certain extent. All other characters are very closely associated. The main causative feature of the plant for increased bud weight (fresh and dry) is C2 (stem girth). Other than C2, C5, C9, C16 and C20, all other characters having significant impact on the single bud weight (fresh).

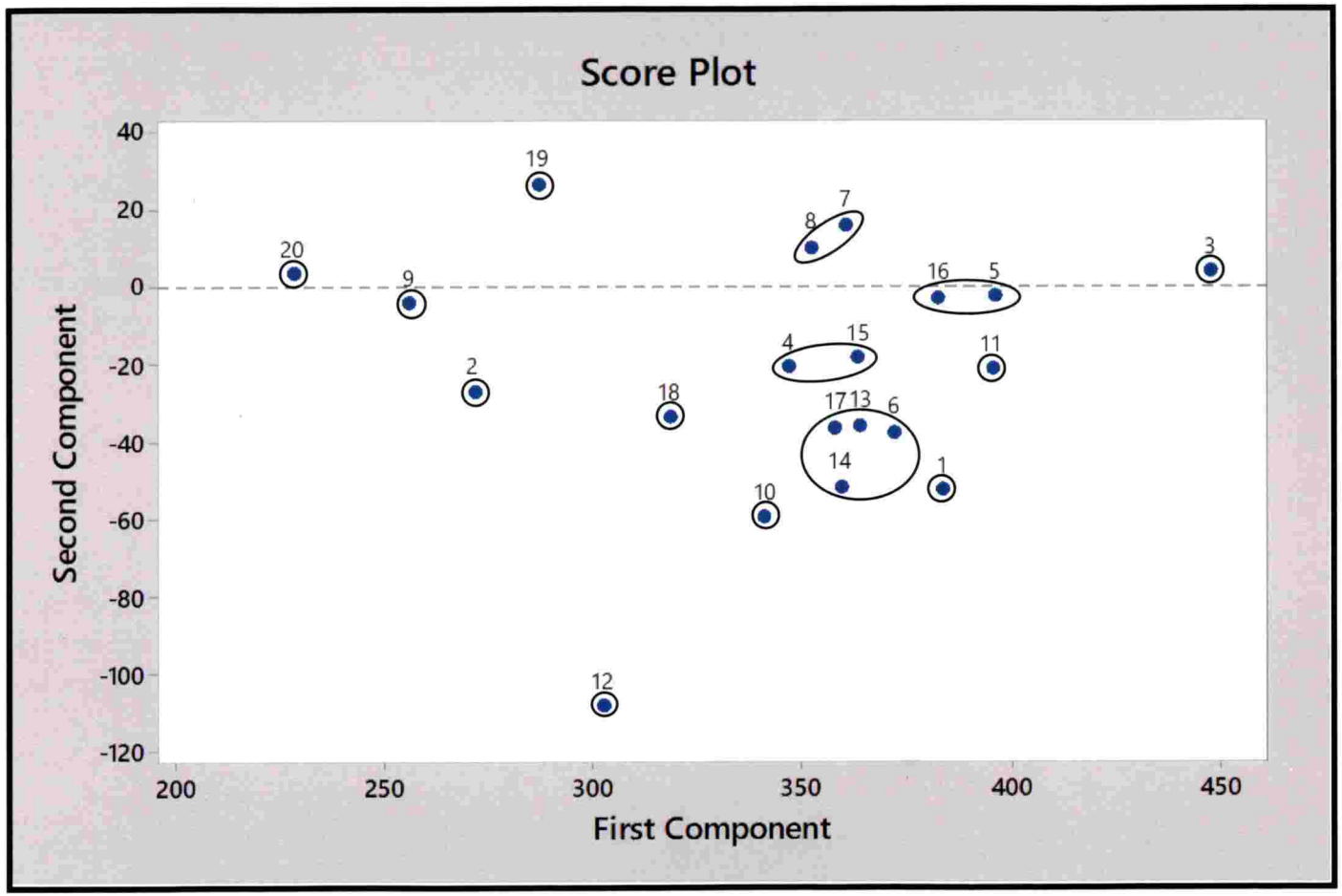


Fig. 2. Identification of clusters based on score plot.

1.BRC-1	2. BRC-2	3. BRC-3	4. BRC-4	5. MRC-5	6. MRC-6	7. MRC-7
8.MRC-8	9. AMC-9	10. AMC-10	11. AMC-11	12. AMC-12	13. AMC-13	14. MMC-14
15. MMC-15	16. BLC-16	17. BLC-17	18. BLC-18	19. MGC-19	20. ANC-20	

Table 58. Parallelism between qualitative and quantitative characters

Qualitative cluster	Number of accessions	Cluster members	Percent of accessions falling in different quantitative clusters													
			I.	II.	III.	IV.	V	VI	VII	VIII	IX	X	XI	XII	XIII	IV
I.	1	BRC-1	100													
II.	3	BRC-2, MMC-15, BRC-4		33.33		66.67										
III.	2	MMC-14, BLC-18						50						50		
IV.	1	MRC-7							100							
V.	1	AMC-12											100			
VI.	2	MRC-5, MRC-6					50	50								
VII.	1	BLC-16					100									
VIII.	3	MRC-8, AMC-10, BLC-17						33.33	33.33		33.33					
IX.	1	MGC-19													100	
X.	1	ANC-20														100
XI.	1	BRC-3			100											
XII.	2	AMC-11, AMC-13						50				50				
XIII.	1	AMC-9								100						

Table 59. Perceived quantitative characterization (tree characters)

Qualitative cluster	Cluster members	Plant height (m)	Girth at 45 cm height	Canopy spread (N-S)	Canopy spread (E-W)	Number of branches
I	BRC-1	9.2	118.5	4.2	3.75	48
II	BRC-2, MMC-15, BRC-4	7.92	78.02	4.8	4.95	46.73
III	MMC-14, BLC-18	10.27	83.15	4.22	4.1	40.5
IV	MRC-7	14.95	99.8	7.42	7.05	47
V	AMC-12	6.5	85.9	4.3	4	38
VI	MRC-5, MRC-6	6.95	90.7	4.97	4.52	42.5
VII	BLC-16	10.3	92.5	5	5.8	44
VIII	MRC-8, AMC-10, BLC-17	7.57	76.70	4.74	4.58	40.59
IX	MGC-19	7.15	55.3	3.15	3.4	31
X	ANC-20	6.8	44.1	3.1	2.95	26
XI	BRC-3	13.6	138.1	4.6	4.35	44
XII	AMC-11, AMC-13	6	85.35	4.85	5.72	48
XIII	AMC-9	5.6	53	3.25	2.9	31

Table 60. Perceived quantitative characterization (leaf characters)

Qualitative cluster	Cluster members	Leaf length (cm)	Leaf breadth (cm)	Leaf area (cm^2)
I	BRC-1	10.98	4.29	31.37
II	BRC-2, MMC-15, BRC-4	11.54	4.24	31.61
III	MMC-14, BLC-18	11.17	3.99	32.25
IV	MRC-7	10.1	3.8	23.98
V	AMC-12	10.04	3.78	29.25
VI	MRC-5, MRC-6	12.56	4.11	33.94
VII	BLC-16	13.09	4.07	37.42
VIII	MRC-8, AMC-10, BLC-17	11.88	3.98	33.97
IX	MGC-19	12.61	4.51	37.49
X	ANC-20	9.66	3.55	23.07
XI	BRC-3	13.77	4.62	39.31
XII	AMC-11, AMC-13	13.67	4.39	40.78
XIII	AMC-9	12.27	4.39	35.17

Table 61a. Perceived quantitative characterization (Bud, flower, fruit and seed characters)

Qualitative cluster	Cluster members	Number of inflorescence/ m^2	Number of flower buds/ inflorescence	Length of flower (mm)	Breadth of flower (mm)	Length of petal (mm)	Length of sepal (mm)
I	BRC-1	114	13.47	21.38	12.39	5.75	3.3
II	BRC-2, MMC-15, BRC-4	75.9	11.82	19.77	12.01	5.52	3.02
III	MMC-14, BLC-18	99	10.70	20.41	12.82	5.54	2.98
IV	MRC-7	43.5	10.47	20.98	12.39	5.8	3.08
V	AMC-12	155.5	9	14.24	12.62	5.14	2.93
VI	MRC-5, MRC-6	83.87	16.63	21.50	12.88	5.32	2.90
VII	BLC-16	69	7.47	19.47	14.74	6.13	2.76
VIII	MRC-8, AMC-10, BLC-17	87.69	10.80	20.94	11.90	5.53	2.79
IX	MGC-19	24.75	6.68	17.19	10.76	5.06	2.61
X	ANC-20	36.25	6.05	16.36	9.85	4.91	2.49
XI	BRC-3	73.75	8.47	19.92	14.82	6.13	2.76
XII	AMC-11, AMC-13	93.62	8.33	19.75	14.81	6.14	2.86
XIII	AMC-9	48.5	7.47	17.96	10.89	5.39	2.55

Table 61b. Perceived quantitative characterization (Bud, flower, fruit and seed characters)

Qualitative cluster	Cluster members	Single bud weight (fresh) (mg)	Single bud weight (dry)(mg)	Mature bud length (mm)	Mature bud diameter (mm)	Period from bud initiation to bud harvest (days)
I	BRC-1	327.05	114	19.06	5.94	112.4
II	BRC-2, MMC-15, BRC-4	292.55	89.1	17.28	5.57	106.98
III	MMC-14, BLC-18	303.66	86.25	17.07	5.28	106.7
IV	MRC-7	324.48	110	18.73	5.55	106.2
V	AMC-12	253.96	75.5	15.26	5.18	115.4
VI	MRC-5, MRC-6	350.83	96.55	14.4	5.83	108.6
VII	BLC-16	348.5	108	17.94	6.04	106.6
VIII	MRC-8, AMC-10, BLC-17	313.66	97.51	18.40	5.07	108.37
IX	MGC-19	274.53	82	15.68	5.19	106.8
X	ANC-20	216.27	66.5	14.94	4.92	111
XI	BRC-3	400.37	128.5	17.73	6.41	110
XII	AMC-11, AMC-13	347.94	94.25	18.10	6.16	114.8
XIII	AMC-9	237.04	76	15.99	4.9	116.2

Table 61c. Perceived quantitative characterization (Bud, flower, fruit and seed characters)

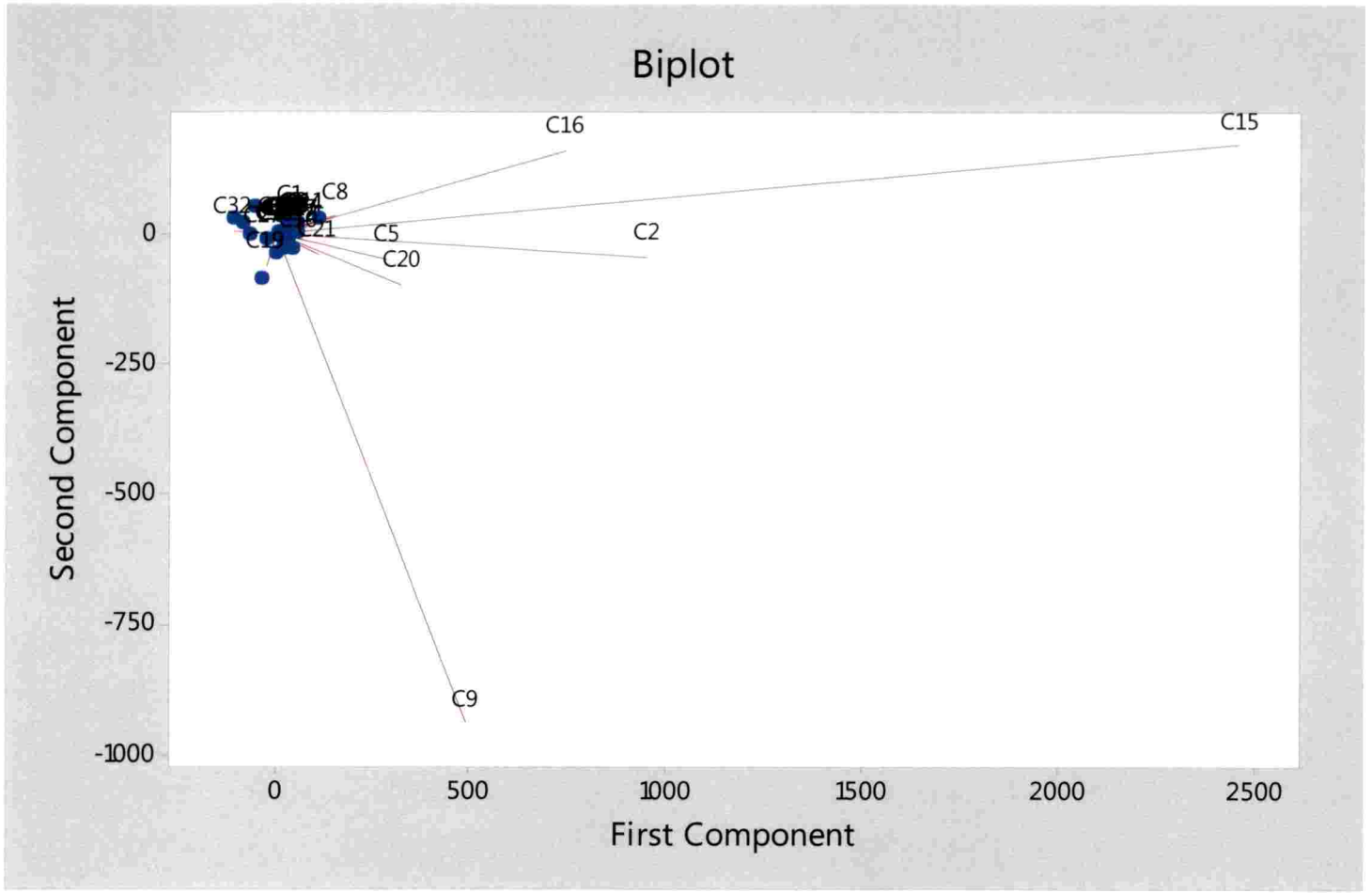
Qualitative cluster	Cluster members	Bud yield per tree (fresh)Kg	Bud yield per tree (dry)Kg	Fruit weight (Fresh)g	Ratio of fruit to seed
I	BRC-1	40.25	11.8	2.77	2.72
II	BRC-2, MMC-15, BRC-4	24.70	8.87	2.49	2.65
III	MMC-14, BLC-18	24.55	9.2	2.31	2.54
IV	MRC-7	34.85	11.08	2.02	2.86
V	AMC-12	26.5	9.8	1.23	2.5
VI	MRC-5, MRC-6	34.87	12.22	2.45	2.49
VII	BLC-16	27.4	8.85	3.13	2.91
VIII	MRC-8, AMC-10, BLC-17	28.74	9.2	2.34	2.97
IX	MGC-19	10	3.44	1.89	2.67
X	ANC-20	3.9	1.29	1.2	2.64
XI	BRC-3	17	5.25	3.53	2.97
XII	AMC-11, AMC-13	19.31	7	3.20	3.07
XIII	AMC-9	8.25	2.25	2.33	3.64

Table 61d. Perceived quantitative characterization (Bud, flower, fruit and seed characters)

Qualitative cluster	Cluster members	Seed length (mm)	Seed breadth (mm)	Seed weight (g)	Time taken for harvest of fruit from flowering (days)
I	BRC-1	18.78	8.43	1.01	88.2
II	BRC-2, MMC-15, BRC-4	17.43	8.37	0.924	92.89
III	MMC-14, BLC-18	17.23	8.11	0.91	96.7
IV	MRC-7	16.34	7.68	0.7	93.8
V	AMC-12	13.95	6.28	0.49	96.9
VI	MRC-5, MRC-6	17.52	8.44	0.98	93.8
VII	BLC-16	18.91	8.69	1.07	89
VIII	MRC-8, AMC-10, BLC-17	17.56	7.45	0.77	93.02
IX	MGC-19	16	7.65	0.71	97.6
X	ANC-20	13.2	6.11	0.45	87.8
XI	BRC-3	19.31	9.19	1.18	90.4
XII	AMC-11, AMC-13	18.91	8.92	1.04	91.05
XIII	AMC-9	16.38	8.06	0.64	96.5

Table 62. Perceived quantitative characterization (Quality characters)

Qualitative cluster	Cluster members	Bud oil (%)	Bud oleoresin (%)	Clove stem oil (%)	Clove stem oleoresin (%)	Eugenol (%)
I	BRC-1	19.6	24.3	5.1	9.8	59.35
II	BRC-2, MMC-15, BRC-4	14.36	20.36	5.31	9.47	61.74
III	MMC-14, BLC-18	14.9	20.85	5.15	8.7	57.52
IV	MRC-7	18.13	23.2	5	8	62.76
V	AMC-12	13.48	18.5	7	10.2	70.58
VI	MRC-5, MRC-6	17.33	21.6	5.35	8.5	62.44
VII	BLC-16	14.66	20.66	6.7	10.3	58.27
VIII	MRC-8, AMC-10, BLC-17	14.93	19.30	5.26	8.64	59.43
IX	MGC-19	14.8	19.5	5.5	8.8	69
X	ANC-20	13.71	20.2	5.8	10	69.61
XI	BRC-3	13.2	21.1	5.2	10.1	61.43
XII	AMC-11, AMC-13	16.10	20.8	5.86	9.75	62.37
XIII	AMC-9	14	19.2	4.85	8.5	69.6



C2-Girth at 45 cm height,
C5-Number of branches,
C9-Number of inflorescence/$m^{2,}$
C15-Single bud weight (fresh),
C16-Single bud weight (dry),
C20-Bud yield per tree (fresh),

Fig. 3. Linkage between major quantitative characters of clove

C1-Plant height, C3-Canopy spread (N-S), C5-Number of branches, C9-Number of inflorescence/m2, C15-Single bud weight (fresh), C16-Single bud weight (dry), C20-Bud yield per tree (fresh), C21-Bud yield per tree (dry), C22-Fruit weight (fresh), C23-Ratio of fruit to seed, C24-Seed length, C25-Seed breadth, C26-Seed weight, C27-Time taken for harvest of fruit from flowering, C28-Bud oil, C29-Bud oleoresin, C30-Clove stem oil, C31-Clove stem oleoresin and C32-Eugenol content of bud

The linkage analysed based on the biplot of Principal Component scores revealed a strong positive association between most of the characters measured except, girth at 45 cm height, number of branches, number of inflorescence/m^2, single bud weight (fresh), single bud weight (dry) and fresh bud yield per tree.

A near zero correlation was observed between number of inflorescence per m^2 and single bud weight (fresh) and single bud weight (dry) as indicated by near perpendicular vectors.

4.3.7.3 Minimum data set characters

The minimum data set for identifying a promising clove accession were generated based on the values of the component loadings of the first two Principal Components, that explained 88.8% of the total variation. The data generated consisted of a vector and a singleton characteristic. The vector of characteristics were girth at 45 cm height, single bud weight (fresh) and single bud weight (dry). The singleton characteristic constituted of number of inflorescence/m^2.

Data set-1	Data set-2
Stem girth at 45 cm height	**Number of inflorescence/m^2**
Single bud weight (fresh)	
Single bud weight (dry)	

4.3.7.4 Genesis of the present investigation

The parallelism between the qualitative and quantitative characterisation yielded in the projection of the quantitative characters based on the major qualitative characters. Thus, an investigator shall first identify a clove tree that possesses a desirable set of qualitative characters and the quantitative characteristics should be mapped accordingly. In the bearing season observe the minimum data set characters. This will optimally sort out ideotype for clove accessions.

4.3.7.5 Illustration of identification of an ideotype using existing data

It revealed accessions BRC-1, MRC-5, and MRC-6 had better ideotype and can be suggested as elite or superior accessions. BRC-1 had 118.5 cm stem girth at 45 cm height, 327.05 g the single bud weight (fresh), 114 g the single bud weight (dry) and the number of inflorescence was 114/m^2. The effective yield worked out was 175.08 g/m^2 which is a higher yield. Similarly, MRC-5 and MRC-6 also had a stem girth at 45 cm height as 90.7 cm. The single bud weight (fresh) was 350.83 g while the number of single bud weight (dry) was 96.55 g. The number of inflorescence was 83.87/m^2 and the effective yield was 134.66 g/m^2.

BRC-3 also can be considered as a best accession because it satisfies all existing data set characters with high value except number of inflorescence/m^2. BRC-3 had 138.1 cm, stem girth at 45 cm height, single bud weight (fresh) as 400.37g, single bud weight (dry) as 128.5g and number of inflorescence was 73.75/m^2. The effective yield worked out corresponded to 80.26g/m^2. All the characters except the number of inflorescence/m^2 were higher in BRC-3.

Variability in yield among the selected clove accessions were analysed using ANOVA. Among the accessions BRC-1, BRC-4, MRC-5, MRC-6, MRC-8, AMC-10, AMC-12, MMC-14 and MMC-15 were significantly superior. Among the accessions higher yield was reported from MRC-6 followed by MRC-5 and BRC-1. This is in confirmation with the data derived from the perceived quantitative characterisation undertaken.

Table 63. Illustration of identification of an ideotype using existing data

Qualitative cluster	Cluster members	Girth at 45 cm height	Single bud weight (fresh)	Single bud weight (dry)	Number of inflorescence /m^2	Effective yield (g/m^2)
I	BRC-1	118.5	327.05	114	114	175.08
II	BRC-2, MMC-15, BRC-4	78.02	292.55	89.1	75.9	79.93
III	MMC-14, BLC-18	83.15	303.66	86.25	99	91.36
IV	MRC-7	99.8	324.48	110	43.5	50.09
V	AMC-12	85.9	253.96	75.5	155.5	105.66
VI	MRC-5, MRC-6	90.7	350.83	96.55	83.87	134.66
VII	BLC-16	92.5	348.5	108	69	55.66
VIII	MRC-8, AMC-10, BLC-17	76.70	313.66	97.51	87.69	92.34
IX	MGC-19	55.3	274.53	82	24.75	13.55
X	ANC-20	44.1	216.27	66.5	36.25	14.58
XI	BRC-3	138.1	400.37	128.5	73.75	80.26
XII	AMC-11, AMC-13	85.35	347.94	94.25	93.62	73.50
XIII	AMC-9	53	237.04	76	48.5	27.53

Table 64. Variability in yield among selected clove accessions

Sl. no.	Accessions ID	Yield
1	BRC-1	**11.8 (3.318)**[a]
2	BRC-2	5.45 (2.296)[abcd]
3	BRC-3	5.25 (2.254)[abcd]
4	BRC-4	10.7 (3.261)[a]
5	MRC-5	**12.2 (3.382)**[a]
6	MRC-6	**12.25 (3.469)**[a]
7	MRC-7	5.7 (2.282)[abcd]
8	MRC-8	9.95 (3.126)[a]
9	AMC-9	2.25 (1.492)[cd]
10	AMC-10	9.85 (3.133)[a]
11	AMC-11	7.4 (2.7)[abc]
12	AMC-12	9.8 (3.126)[a]
13	AMC-13	6.6 (2.571)[abc]
14	MMC-14	11.5 (3.378)[a]
15	MMC-15	10.75 (3.27)[a]
16	BLC-16	8.85 (2.974)[ab]
17	BLC-17	8.1 (2.834)[ab]
18	BLC-18	6.9 (2.606)[abc]
19	MGC-19	3.44 (1.845)[bcd]
20	ANC-20	1.29 (1.121)[d]
CD (0.05)		**1.231**

Figures in parenthesis are square root transformed values

DISCUSSION

5. DISCUSSION

Clove (*Syzigium aromaticum* (L) Merr. & Perry) is one of the most valued spice in the world. It is used as a culinary spice in many eastern and western dishes, a staple ingredient in most curried dishes, spicy fruit cakes, sauerkraut etc. It also has wide usage in dentistry, cosmetics and perfumery (Teuscher *et al.*, 2005; Duclos, 2012). The demand of clove worldwide is increasing but presently there is no released variety for clove in India. Hence considering the requirement of the farmer, there is a need to identify a suitable high yielding accession as well as a suitable ideotype in clove.

In India, the genetic base of clove is narrow hence variability in clove is very limited. The origin of present-day clove populations were from very limited trees introduced to our country (Nybe *et al.*, 2006). Besides this, self-pollinating nature of the crop also led to lack of variability. In India, generally local types were under cultivation and no true variety of clove was recognized.

Till date no detailed cataloguing of the varied features of clove has been reported. Hence, identification and assessment of the existing variability is necessary for taking up successful crop improvement programmes in clove.

5.1. SURVEY

During the academic research, survey was carried out in fifteen different locations from the clove growing areas of Trivandrum, Kollam and Pathanamthitta district of Kerala and Kanyakumari district of Tamil Nadu. Survey was carried out to identify clove accessions showing morphological variability, diverse origin, superior yield and unique characters.

After surveying fifteen clove growing locations, accessions which showed special characters were spotted. The special characters considered for selection of clove accessions included canopy shape, different flower bud size, clustering and colour of flower bud, season of bud forming as well as higher yield. Passport data

of selected twenty clove accessions which were identified as BRC-1, BRC-2, BRC-3, BRC-4, MRC-5, MRC-6, MRC-7, MRC-8, AMC-9, AMC-10, AMC-11, AMC-12, AMC-13, MMC-14, MMC-15, BLC-16, BLC-17, BLC-18, MGC-19 and ANC-20 were collected and presented in table 4a, 4b, 4c and 4d. All the clove accessions selected belonged to the clove plantations of the Western Ghats region and at an altitude of 45 m above MSL to 850 m above MSL. The selected accessions were from a latitude of 8°22'33" to 9°02'23" and of longitude 76°55'13" to 77°27'20". During the time of selection, the susceptible/tolerant nature to leaf spot disease was also noted. Qualitative and quantitative characterization was done *in situ* for the selected twenty clove accessions to identify morphological and biochemical variants.

The soil condition plays a major role for the robust establishment of a plantation. The soil parameters namely N, P, K, organic carbon and soil pH were analysed and the recommended nutrients were applied based on the soil test data. This was undertaken to reduce the effect of nutrients on the yield parameters.

Pool *et al.* (1986) surveyed one hundred clove trees of 34 wild and cultivated populations in the north and central Moluccas. There was considerable variation among wild clove trees than cultivated types. Good morphological variation in several cultivated populations especially in terms of flower bud, leaf and flower bud clusters characters were reported. The morphological variants in clove were identified after surveying major clove growing areas in Tamil Nadu and Kerala (Krishnamoorthy and Rema, 1992; Krishnamoorthy and Rema, 1995 and Balakrishnamoorthy and Kennedy, 1999).

5.2 CHARACTERIZATION AND EVALUATION OF SELECTED CLOVE ACCESSIONS

Descriptors for clove was not developed till now. Hence a minimal descriptor considering qualitative and quantitative parameters was developed considering the descriptor of other perennial crops published by National Bureau

of Plant Genetic Resources, New Delhi and International Plant Genetic Resources Institute (PPVFRA, 2012 and IPGRI, 2003).

5.2.1 Morphological characterization

Morphological characters are those charcters that are scored visually, which are genetic markers whose inheritance can be followed with the naked eye (Kamra and Kathuria, 2016). These were naturally occurring variants of a particular plant species.

In India, only little work has been done on identification of clove accessions based on morphological markers. Both qualitative and quantitative characters were used in the present study for morphological characterization of selected clove accessions.

5.2.1.1 Qualitative characters

The qualitative characters observed in the selected twenty clove accessions included tree, leaf, bud, flower, fruit and seed characters. Of the 21 qualitative characters observed considerable variation was noticed for 15 characters. Qualitative characters like leaf arrangement, position of flower, colour of peduncle, mature fruit colour, ripe fruit colour and seed colour were non variable characters among the accessions

5.2.1.1.1 Tree characters

5.2.1.1.1.1 Canopy shape

Four types of canopy shapes were observed in the selected clove accessions which included elliptical, cylindrical, conical and pyramidical shapes. Majority of the accession possessed elliptical shapes (40%) followed by cylindrical (20%), conical (20%) and pyramidical shapes (20%). Pool *et al.* (1986) in the Moluccan islands recorded three types of canopy conformation i.e. round, pyramidical and cylindrical. Pyramidical shaped trees usually grow with less vertical growth. Hence,

most of the lowest branches may be picked from the ground. With respect to conical shaped tree, top branches become less accessible to harvest. But conical shaped trees help in the accommodation of more number of plants per unit area. With suitable canopy management by training and pruning conical shaped trees become ideal for high density planting. Thus, canopy shape can become a deciding factor in determining the plant density.

5.2.1.1.1.2 Branching pattern

Trees come in a variety of forms based on their branching patterns. Canopy shapes associated with its branching pattern of a tree plays a major role in the capture of solar radiation (Maiti *et al.*, 2015). The branching pattern of the selected clove accessions were semi-erect pattern (55%), followed by irregular (35%) and erect (10%). Brinigriew (1933) recorded that farmers in West Sumatra recognized differences in branching conformation of clove. In nutmeg, erect and spreading were two types of branching pattern reported (Vikram, 2016). The present classification obtained in the study is a confirmation of the reports of Brinigriew (1933).

5.2.1.1.2 Leaf characters

5.2.1.1.2.1 Colour of young leaf

The colour of young leaf among the selected and evaluated accessions were red pink with light green tinge in 85%, followed by yellow green with light green tinge 10 % and purple red with light green tinge in 5 %. Purseglove *et al.* (1981) observed that new leaves which appear in the clove flushes are bright pink in colour.

5.2.1.1.2.2 Colour of mature leaf

Among the twenty evaluated accessions, sixty five per cent were dark green coloured mature leaf and the rest were green (35%) coloured. Dark green colour thus seems to be the predominant colour of mature leaf. Purseglove *et al.* (1981) reported dark green coloured mature leaf in clove. In nutmeg after evaluating forty-

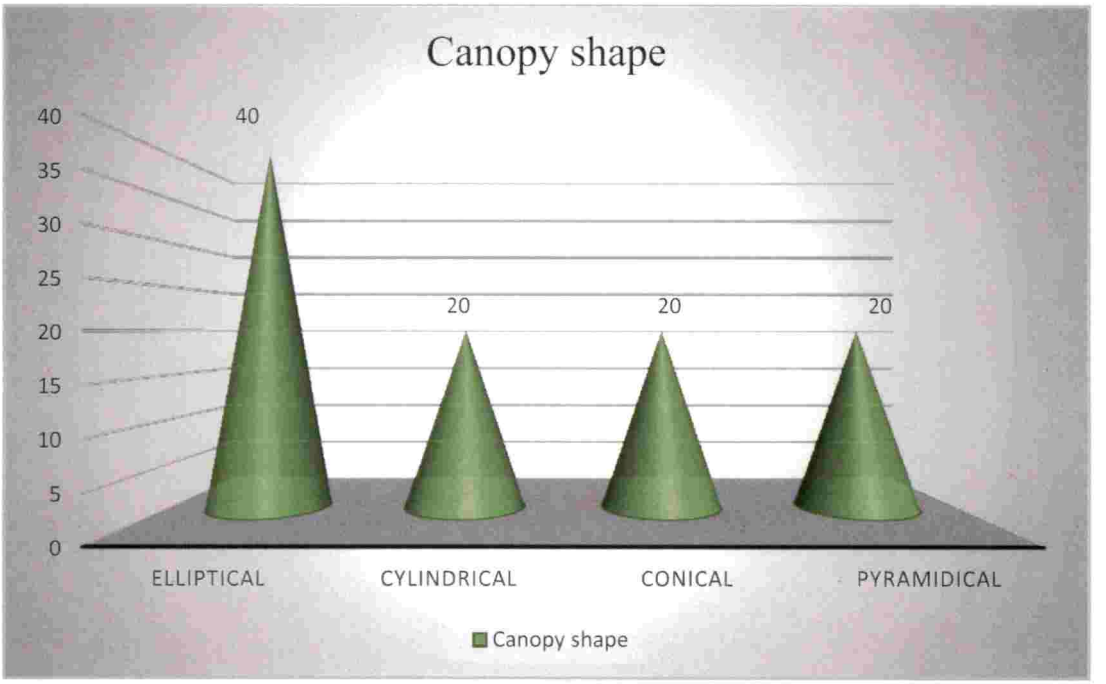


Fig. 4. Distribution of canopy shape among the clove accessions

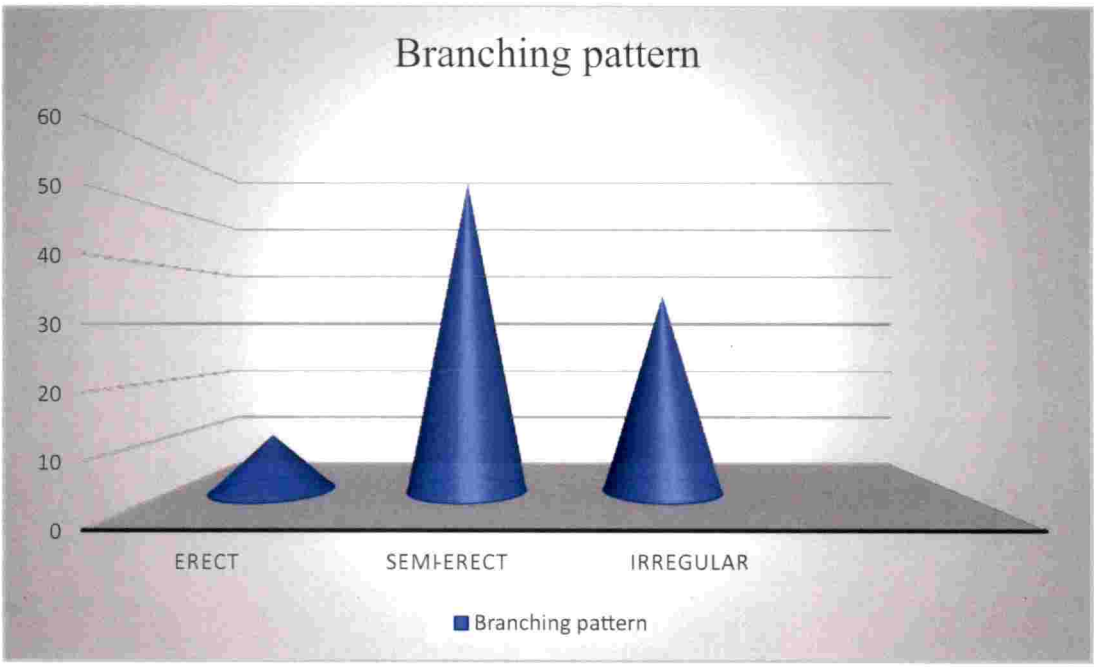


Fig. 5. Distribution of branching pattern among the clove accessions

six accessions three different coloured mature leaf was recorded *viz.* green, dark green and light green (Vikram, 2016). In cinnamon, Sahoo *et al.* (1998) grouped the leaves as light green and dark green.

5.2.1.1.2.3 Leaf lamina shape

A slight variation was observed with respect to leaf lamina shape among the clove accessions evaluated. The predominant leaf lamina shape was lanceolate (85%) followed by narrowly elliptical (15%). All selected accessions had lanceolate leaf lamina shape except BRC-3, AMC-11 and AMC-13. In an earlier study, Purseglove *et al.* (1981) also reported lanceolate or narrowly elliptic and occasionally narrowly obovate leaf lamina shape in clove.

5.2.1.1.2.4 Leaf apex shape

Acuminate and acute were two types of leaf apex shapes noticed among the twenty selected accessions. The accessions which had narrowly elliptic leaf lamina shape had acute leaf apex shape which was represented by BRC-3, AMC-11 and AMC-13. Purseglove *et al.*, (1981) reported leaf apex shape as shortly or broadly bluntly acuminate.

5.2.1.1.3 Bud, flower, fruit and seed characters

5.2.1.1.3.1 Bud forming season

Variation in bud forming season was observed among the accessions evaluated in the study. Peak bud forming period could be grouped as early (late October to late November), mid (December to January) and late (February to March) season types. Majority of the accessions were mid-season (70%) and remaining accessions showed early and late seasons with an equal distribution (15%). The accessions BRC-1, ANC-20 and AMC-13 were early yielders and AMC-9, MMC-14 and BLC-18 were late yielders. Vikram (2016) grouped the flowering season in nutmeg into early flowering (July), mid flowering (late July to early August) and late flowering (late August).

Early season with synchronised flowering types might have an added advantage in clove.

5.2.1.1.3.2 Bud clustering habit

Clove inflorescence is paniculate cyme and consists of many groups of three flowers each. The observation on bud clustering habit revealed that majority of the accessions were showing combination of 1,2,3 flower buds per cluster (85%) and the rest were combination of 1,2,3,4,5 flower buds per cluster (15%). The accessions BRC-1, MRC-5 and MRC-6 had combination of 1,2,3,4,5 flower buds per cluster. In mangosteen fruit crop, Makhonpas *et al.* (2015) reported two types of flower clustering habit after morphological characterization of twenty four selected accessions. The majority of the accessions showed one flower per cluster (81.8%) followed by combination of 1 and 2 flowers per cluster (18.2%). The bud clustering nature in clove seems to be an indicator of good yield as revealed from the superiority in yield of the BRC-1, MRC-5 and MRC-6.

5.2.1.1.3.3 Bud size

After evaluating twenty selected clove accessions, buds were categorized into small, medium and large based on bud length. Majority of the evaluated accessions had medium sized buds followed by large and small. The accessions BLC-16, BRC-3, AMC-11 and AMC-13 had large sized buds. Size of bud is also an important criterion of yield. Balakrishnamoorthy and Kennedy (1999) reported three different types of clove flower buds *viz.*, small, medium and big. According to them king cloves had a length of 1.6 to 1.8 cm and breadth of 1.2 to 1.6 cm. The medium sized clove had a length of 1 to 1.2 cm with a breadth of 0.6 to 0.8 cm and for mini clove the length and breadth ranged from 0.75 to 0.8 cm and 0.4 to 0.5 cm respectively. Makhonpas *et al.* (2015) categorized flower size of mangosteen into small (58.3%) medium (41.7%).

5.2.1.1.3.4 Petal colour

The flower of clove composed of four sepals and four petals. In clove, two different types of petal colours were recorded *viz.* light green with pinkish tinge and green brown coloured. In mangosteen, three types of petal colours namely yellow green, yellow with red/pink margin and green were reported (Makhonpas *et al.*, 2015). The characterization of flower morphology of 26 accessions of *Garcinia atroviridis* done by Bayu *et al.* (2018) reported yellow green coloured petal.

5.2.1.1.3.5 Sepal colour

Yellow green and dark purple red coloured sepal were observed in the selected clove accessions. *Garcinia mangosteena* Linn. exhibited yellow, yellow green, green, yellow with red margin sepal colour (Makhonpas *et al.*, 2015). Gogoi (2015) reported reddish coloured petal in *Garcinia lanceaefolia* and light green petal in *Garcinia pedunculata* and *Garcinia xanthochymus.*

5.2.1.3.6 Colour of stigma

Two different colours were recorded with respect to colour of stigma. Light green was the more common colour of stigma followed by yellow green. AMC-9 showed yellow green stigma while all other accessions has light green stigma. Colour of stigma lobe was dark brown in mangosteen (Makhonpas *et al.*, 2015).

5.2.1.3.7 Colour of hypanthium

The predominant hypanthium colour was light red pink and an unique accession namely AMC-9 exhibited dark purple red coloured hypanthium among the selected accessions. Pool *et al.* (1986) reported that calyx tube colour or hypanthium colour in clove varies from scarlet/red to green/yellow.

5.2.1.3.8 Fruit shape

Ripe fruits in cloves are called 'mother of cloves'. In the present study, two different fruit shapes were recognized *viz.* oblong and elliptic shapes. Round, oval,

ovoid and pyriform were the four different forms of fruit shape reported in nutmeg (Vikram, 2016).

5.2.1.3.9 Seed shape

After recording twenty selected clove accessions, the shape of the seed was categorized into oblong and elliptic. Purseglove *et al.* (1981) and Ravindran *et al.* (2006) reported oblong shaped seed in clove. The shape of the seed in clove was totally dependent on the fruit shape. All accessions which had oblong fruit produced oblong seeds and elliptical fruit produced elliptical seeds.

5.2.2 Bivariate analysis of major qualitative characters

Association of major qualitative characters was done by cross tabulating two qualitative characters by chi-square test.

In clove, few quality characters observed were dependent. The major association among the quality characters are canopy shape with branching pattern; colour of young leaf with petal colour, sepal colour and colour of stigma; colour of mature leaf with bud size; and fruit shape with seed shape.

Few characters stand alone and might be specific to locale. Thus, majority of the characteristics of the clove varied spatially and temporally.

No association was noticed between canopy shape with bud clustering habit, bud size, fruit shape and seed shape. Branching pattern was not associated with bud clustering habit, bud size, fruit shape and seed shape. Similarly, colour of young leaf was also not associated with bud clustering habit, bud size, fruit shape and seed shape. No association of colour of mature leaf with fruit shape, seed shape, petal colour, sepal colour and colour of stigma. Leaf apex shape was also not associated with bud clustering habit, fruit shape and seed shape. No association was observed between leaf lamina shape and bud clustering habit, fruit shape and seed shape.

5.2.3 Clustering based on qualitative characters

Cluster analysis based on fifteen qualitative characters revealed that all the twenty accessions could be grouped into 13 clusters at 80 per cent similarity.

Cluster analysis was useful in identifying unique group of accessions. Among the thirteen clusters, Cluster I included BRC-1, Cluster II included BRC-2, MMC-15 and BRC-4, Cluster III contained MMC-14 and BLC-18, Cluster IV with MRC-7, Cluster V contained AMC-12, Cluster VI with MRC-5 and MRC-6, Cluster VII included BLC-16, Cluster VIII MRC-8, AMC-10 and BLC-17, Cluster IX contained MGC-19, Cluster X with ANC-20, Cluster XI included AMC-11 and AMC-13 and Cluster XIII included AMC-9 respectively. Accessions in the cluster II *viz.* BRC-2, BRC-4 and MMC-15 were identical in all the characters except canopy shape and branching pattern. Accessions in the cluster VIII possessed identical and close association fruit and seed shape characters. The subcluster in cluster II were II-A and II-B. Sub cluster II-A included accessions BRC-2 and MMC-15. Subcluster II B included BRC-4 alone. In the cluster II all qualitative characters including leaf, bud, flower, fruit and seed characters of BRC-2, MMC-15 and BRC-4 were the same except the tree characters like canopy shape and branching pattern. BRC-2 and MMC-15 had semi erect branching pattern while BRC-5 had irregular branching pattern. The canopy shape of BRC-2 was cylindrical while that of BRC-4 and MMC-15 was elliptical. The cluster VIII consisted of two subclusters VIII-A and VIII-B. MRC-8 and AMC-10 belonged to subcluster VIII-A and BLC-17 to subcluster VIII-B. In cluster VIII, the three accessions MRC-8, AMC-10 as well as BLC-17 had all similar qualitative characters except canopy shape and colour of mature leaf. Cluster I, IV, V, VII, IX, X, XI and XIII had only single solitary accessions and possessed qualitative traits distinct from all other accessions. In the thirteen clusters identified, cluster II and cluster VIII had two subclusters each. The accession AMC-9 in cluster XIII showed maximum diversity due to elliptical canopy shape with irregular branching pattern having purple red young leaf and green mature leaf. The bud forming season was late with dark purple

red colour for hypanthium and sepal, green brown colour for petal and yellow green colour for stigma.

Cluster VI and XII included two accessions each. MRC-5 and MRC-6 belonged to cluster VI while AMC-11 and AMC-13 belonged to cluster XII. MRC-5 and MRC-6 had pyramidical canopy shape with irregular branching pattern, combination of 1,2,3,4,5 flower buds/cluster with medium bud size with mid bud forming season which made the cluster different from other. AMC-11 and AMC-13 had pyramidical canopy shape with irregular branching pattern, narrowly elliptic leaf lamina shape with early bud forming season producing large bud size.

5.2.3 Quantitative characters

5.2.3.1 Tree characters

Between the twenty selected clove accessions, the plant height ranged from 5.15 m to 15.25 m (Table 48). The highest tree height among the selected accessions was BLC-18. Accession AMC-13 had the lowest height (5.15 m) followed by MMC-14 (5.3 m). As the canopy shape is a navigator of the height of the plant, in accessions with pyramidal shaped canopy the plant height ranged from 6.50 to 7.35m while for conical shape the plant height ranged from 7.35 m to 13.6m.

Tree girth is an important morphological character for assessing the productivity in clove (Balakrishna *et al.*, 1998) and it could be measured at 45 cm height from the base of the tree (Kennedy and Nageswari, 2000). The data revealed that the girth at 45 cm height showed wide range from 44.1 cm to 138.1 cm. The girth at 45 cm was the highest for BRC-3 and lowest for ANC-20.

Tree canopy spread is another important growth parameter. The canopy spread N-S varied from 3.1 m to 7.42 m and it was the highest in MRC-7 and lowest for ANC-20. The canopy spread E-W ranged from 2.95 m to 7.9 m and was the highest for AMC-11 and lowest for ANC-20. During the survey, the highest flower

clusters were noticed on eastern and western direction and where maximum tree exposures to sunlight was possible.

Number of branches in the tree is another yield influencing character. The number of branches ranged from 26 to 55. AMC-11 showed maximum number of branches. The number of branches was lower in ANC-20 and AMC-9. The number of branches had an influence on the yield.

5.2.3.2 Leaf characters

Leaf characters are easily observable qualitative characters. The minimum leaf length in the selected accession was 9.66 cm in ANC- 20 and the maximum in MRC-5 i.e. 13.93 cm. Leaf breadth of the selected accessions varied from 3.55 cm to 4.72 cm. SA-3 is one among the 24 clove accessions maintained at Horticulture Research Station, Pechiparai revealed that the highest leaf length of 16.5 cm and leaf breadth 6.2 cm (AICRP, 2015).

Leaf area ranged from 23.07 cm^2 in ANC-20 to 42.93 cm^2 in AMC-11. Variation in the leaf area might be due their different leaf length and breadth. Assessment of leaf area was one of the important method of determining the variability and productivity in clove (Balakrishnan *et al.*, 1998).

5.2.3.3 Bud characters

5.2.3.3.1 Number of inflorescence/m^2

Recorded by fixing 1 m^2 quadrats during peak bearing season on all the four sides of the tree. The number of inflorescence /m^2 was the maximum in AMC-12 (155.5) followed by AMC-10 and the minimum in ANC-20 (36.25). The number of inflorescence/m^2 had an influence on the yield. AMC-12 was found to be a moderately high yielder regular bearing as revealed from the yield data. The number of inflorescence/m^2 is a highly variable character as inferred from the descriptive statistics where the standard deviation was noted 31.43. In nutmeg, Vikram (2016)

reported that number of flowers per 10 cm^2 and number of fruits per m^2 was significantly different among the forty six accessions evaluated.

5.2.3.4 Number of flower buds/inflorescence

The number of flower buds/inflorescence varied from 6.05 in ANC-20 to 18.21 in accession MRC-6. The number of flower buds/inflorescence was higher in MRC-6, MRC-5 (15.05) and BRC-1 (13.47). The bud yield per tree was also the higher in these accessions showing that number of flower buds /inflorescence had an influence in determining the yield of plant. In a study, Balakrishnamoorthy and Kennedy (1999) reported that number of flower buds/inflorescence varies from 10 to 20. Krishnamoorthy and Rema (1992) concluded that number of flower buds per inflorescence and number of inflorescences per branch determines the yield in clove.

5.2.3.5 Bud characteristics

The ultimate economic end product in clove concerned to farmer is matured unopened flower bud. The single bud weight (fresh) and single bud weight (dry) was the highest for BRC-3. The single bud weight (dry) ranged from 66.5 to 128.5 mg among different accessions. Higher values for single bud weight (dry) was noted in accessions like BRC-3 (128.5 mg), MRC-8 (120 mg), BRC-1 (114 mg), MRC-7 (110 mg), BLC-18 (108 mg) and MRC-5 (101.5 mg).

The mature bud length varied from 14.94 mm to 19.06 mm while the mature bud diameter ranged from 4.9 mm in AMC-9 to 6.41 mm in BRC-3. Accessions BRC-3, AMC-11, AMC-13 and BLC-16 were large buds as revealed from the table 51a representing qualitative characters. The fresh mature bud diameter of the large buds ranged from 4.9 mm to 6.41mm. The single bud weight (dry) of BRC-3 was the highest among the accessions which might be explained by the highest mature bud diameter of the accession (6.41 mm) showing the large size of the bud. Balakrishnamoorthy and Kennedy (1999) reported three different types of clove

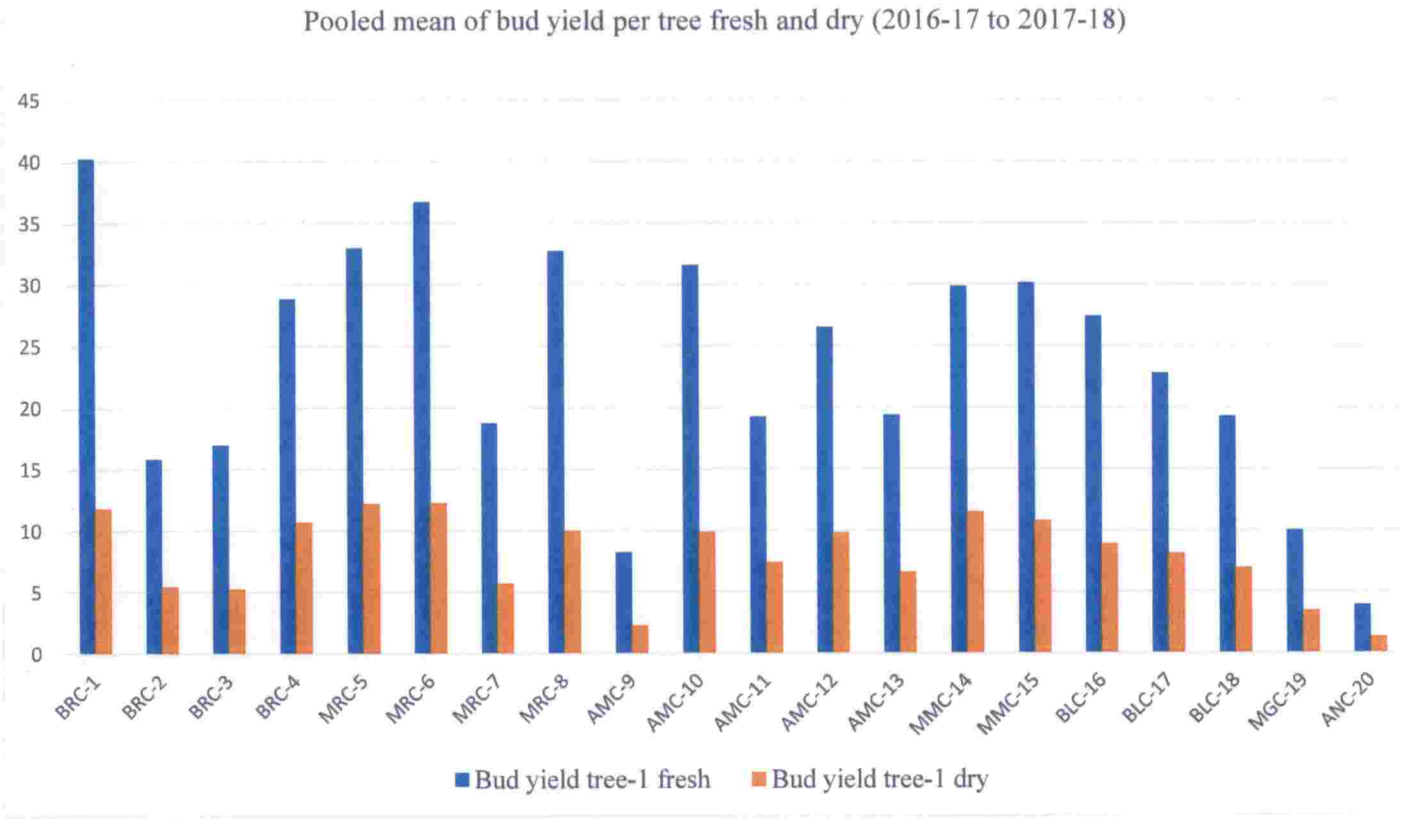


Fig 6. Pooled mean of bud yield per tree fresh and dry (2016-17 to 2017-18)

flower buds *viz*., small, medium and big. The king cloves had a length of 1.6 to 1.8 cm, breadth of 1.2 to 1.6 cm while that of medium sized clove had a length of 1 to 1.2 cm with a breadth of 0.6 to 0.8 cm and for mini clove, the length and breadth ranged from 0.75 to 0.8 cm and 0.4 to 0.5 cm respectively. However, in the accessions studied the longest bud length observed was 1.906 cm in BRC-1 compared to 1.6 to 1.8 cm referred by Balakrishnamoorthy and Kennedy (1999). The period taken from bud initiation to bud harvest ranged from 103.8 to 118.4 days. Thangaselvabai *et al.* (2010) concluded that flower buds takes about 4 to 6 months to become ready for harvest.

In the present investigation, the selected accessions belonged to the age group of 25 to 40 years. In clove, yield stabilises after 15 years. Bud yield per tree fresh and dry was recorded for two consecutive years i.e. 2017 and 2018. Two year pooled mean of bud yield per tree fresh varied from 3.9 to 40.25 kg. BRC-1, MRC-5, MRC-6, MRC-8, AMC-10 and MMC-15 were good yielders and yielding more than 30 kg/tree as revealed from pooled mean. AMC-9 and ANC-20 were lower yielders. However, bud weight per tree dry was the highest for MRC-6 (12.25kg/tree) followed by MRC-5 (12.2 kg/tree). The dry recovery of clove ranged from 24.9 per cent to 38.44 per cent. Accession AMC-11 showed the highest dry recovery. Most of the accessions showed biennial nature, while the yield gap was less in accessions like AMC-12 and BLC-16. Yield in clove may be influenced by weather and the previous crop. According to Purseglove *et al.* (1981), it was rare to get two good yield in successive years due to the physical shock of picking.

5.2.3.4 Flower characters

The variation observed was negligible with respect to flower characters. The length of flower ranged from 14.24 mm to 21.84 mm and the breadth ranged from 9.85 mm to 14.82 mm. The number of sepal and petal was constant while the length of sepal ranged from 2.49 mm to 3.3 mm. The petal length varied from 4.91 mm in ANC-20 to 6.3 mm in AMC-11.

5.2.3.5 Fruit and seed characters

Clove fruit is single seeded drupe and popularly known as mother of clove. The fruit weight fresh ranged from 1.2 g in ANC-20 to 3.53 g in BRC-3. The fruit to seed ratio ranged from 2.37 to 3.64. The highest seed length corresponded to highest fruit length and was noted in BRC-3. The seed length varied from 13.2 to 19.31 mm and seed breadth from 6.11 mm to 9.19 mm in the selected accessions. The seed weight was the highest for BRC-3 (1.18 g) followed by 1.1 g in AMC-11. The time taken for harvest of fruits from flowering ranged from 86.8 to 97.6 days. According to Purseglove *et al.* (1981) fruits 2.5 to 3.5 cm long, 1.2 to 1.5 cm in diameter, tapering at each end, surmounted by the four enlarged fleshy calyx lobes and with fleshy pericarp of 2 to 3 mm thick. The seed is about 2 cm long with purplish colour testa, with two large cotyledons and no endosperm. Seed characters of progenies of 14 elite clove trees revealed no appreciable variation for 100 fruit weight, 100 seed weight, fruit breadth, fruit length, seed breadth and seed length (Krishnamoorthy and Rema, 1994b). Ravindran *et al.* (2006) reported that clove fruit contains one oblong shaped seed of about 1.5 cm length.

5.2.3.6 Quality parameters

The bud oil recorded a maximum value of 19.6 per cent in BRC-1 and minimum value of 12.53 per cent in the accession BLC-17. The stem oil ranged from 3.6 per cent to 7.2 per cent in the selected accessions. Purseglove *et al.* (1981) and Ravindran *et al.* (2006) concluded that in dried clove buds essential oil yield varies from 15 to 17 per cent and 14 to 21 per cent respectively.

The bud oleoresin extracted varied from 16.9 to 24.3 per cent in the accessions. Accession BRC-1 yielded the highest and BLC-17 yielded the lowest oleoresin content among the accession evaluated with petroleum benzene solvent. Recovery of the oleoresin varies according to the solvents which were used for extraction. According to the Naves (1974), the recovery of oleoresin was 18 to 22 per cent with benzene solvent.

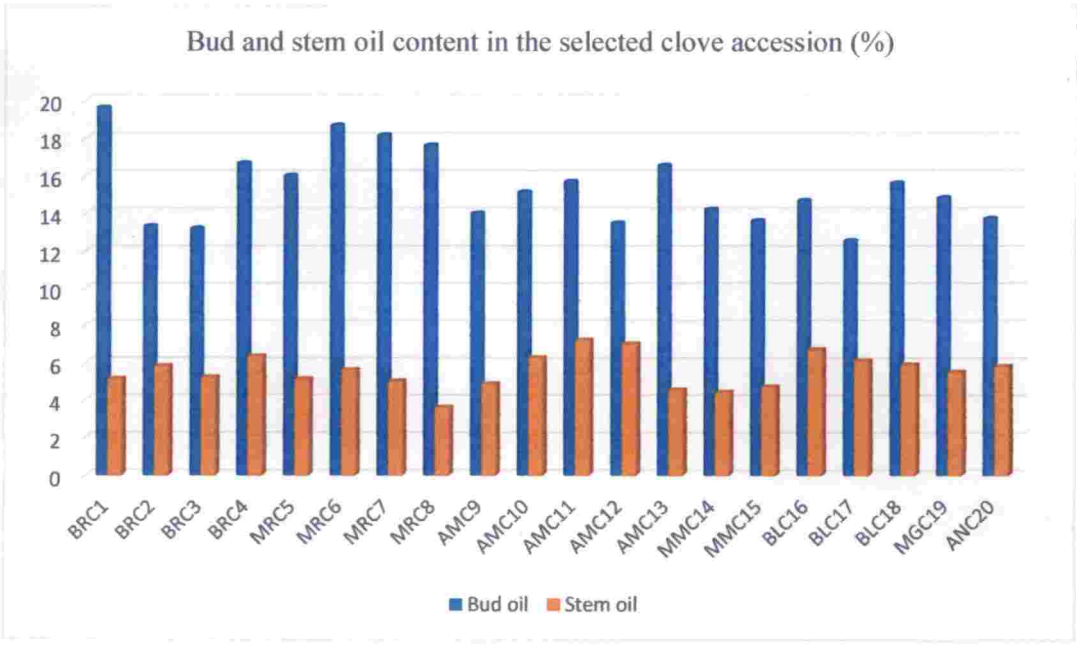


Fig. 5. Bud and stem oil content in the selected clove accession

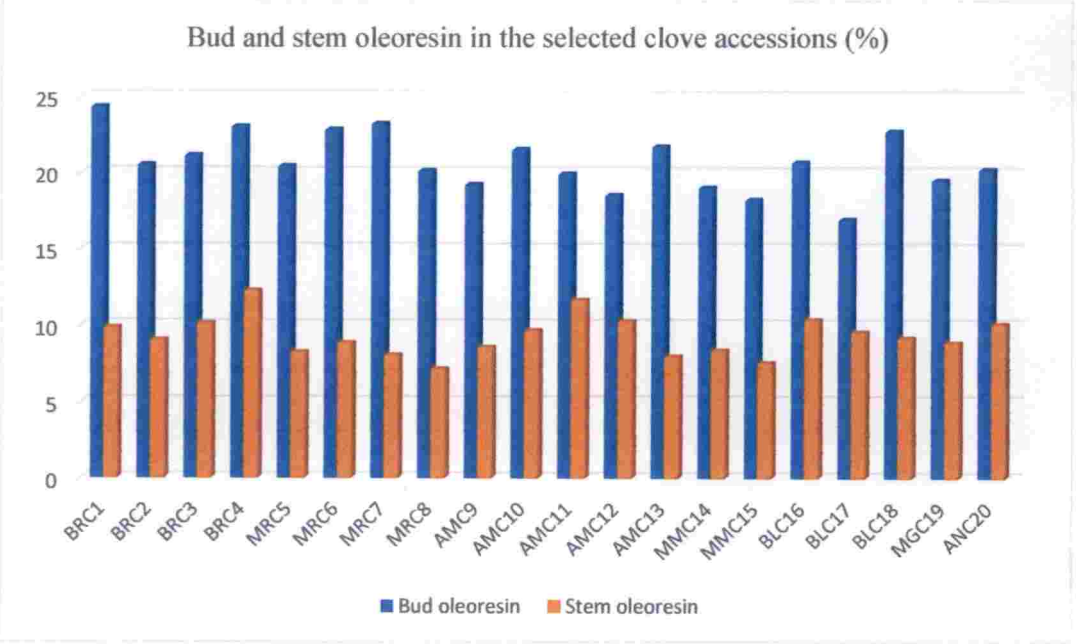


Fig. 6. Bud and stem oleoresin content in the selected clove accession

Stem oleoresin content among the selected accessions ranged from 7.1 per cent in accession MRC-8 and 12.2 per cent in BRC-4.

Major constituent of clove essential oil is eugenol. The eugenol content between accessions ranged between 54.29 and 70.77 per cent. The highest eugenol content was obtained from accession BLC-17 and the lowest was from MRC-8. Zachariah and Leela (2006) reported that essential oil content ranged from 12.9 to 18.5% in clove buds and 3.0 to 7.7% in pedicel while the eugenol content varied from 44 to 55% in bud oil and 60.0 to 72.4% in the oil from pedicel.

The variation in the amount of essential oil and oleoresin in the bud and stem of clove among different accessions might be due to the genetic as well as environmental effect. Arslan *et al.* (2004) opined that the amount of secondary compounds like essential oils are affected by genetic factors, climate, soil and cultivation techniques.

5.2.3.7 GC MS profile of bud oil of selected clove accessions

GC MS profiling studies of the essential oil from clove buds of the elite clove accessions like BRC-1, BRC-3, MRC-5 and MRC-6 revealed the per cent composition of 25 different compounds. The major constituents of the bud oil included p-eugenol, eugenyl acetate, β-caryophyllene, β-cubebene and 4-Quinolinol.

In the present study, the major component of clove bud oil was eugenol and it ranged from 59.36 to 62.53% among the elite accessions. An average eugenyl acetate was found to be 21.229% and ranged from 19.647 to 23.046%. β-Caryophyllene ranged from 6.54% to 8.896%, β-Cubebene ranged from 0.83 to 1.11%, and 4-Quinolinol from 0.557 to 3.378%. The average α-humulene was found to be 0.96 and ranged from 0.82 to 1.1%. GC-MS analysis carried out in essential oil from Turkish clove revealed 18 compounds representing 99.95 % of essential oil. The main constituents were eugenol (87%), eugenyl acetate (8.01%) and β-caryophyllene (3.56 %) (Alma *et al.*, 2007).

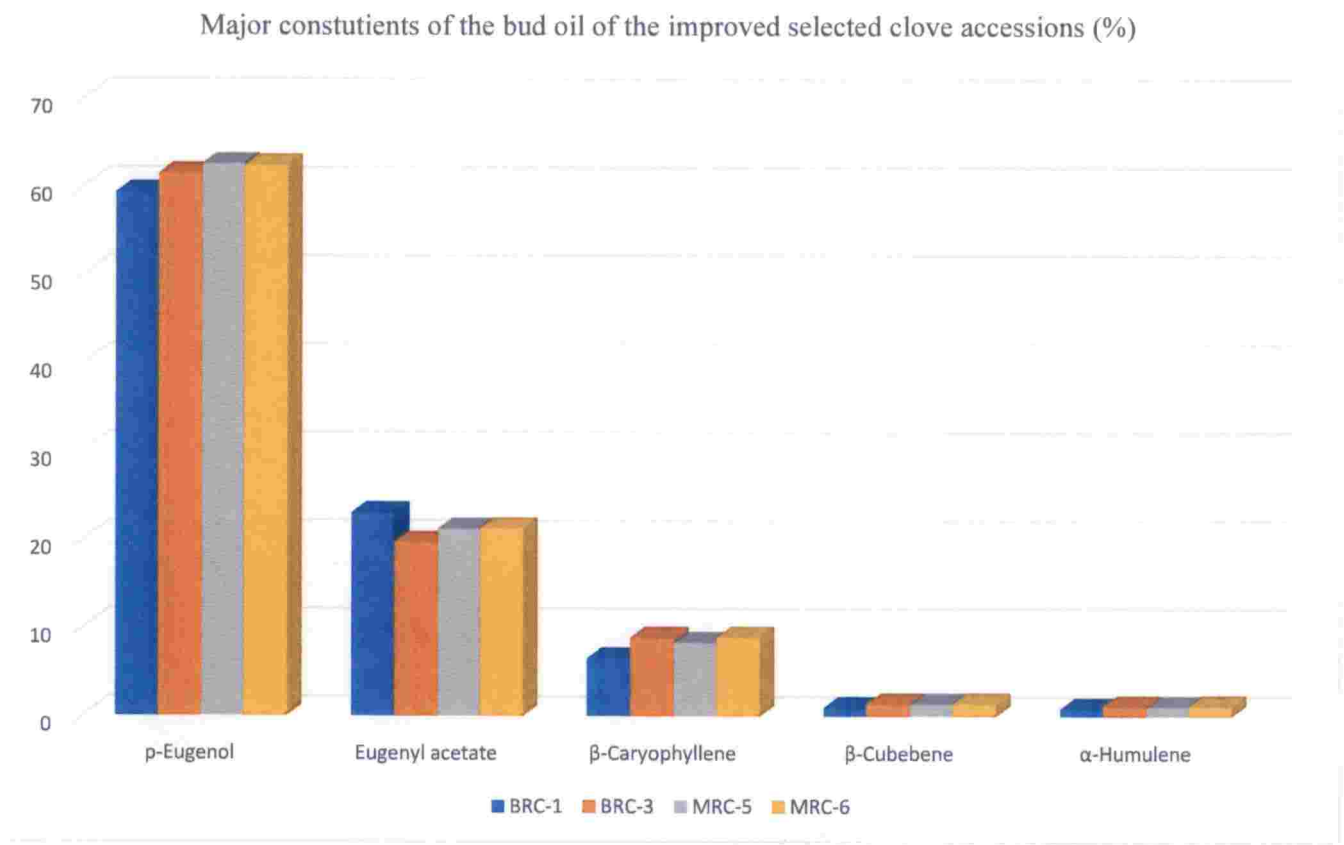


Fig.7. Major constituents of the bud oil of the improved selected clove accessions

Major constituents in clove oil responsible for their flavour based on origin from Toli-Toli and Bali analysed using GC-MS revealed eugenol, caryophyllene, α-humulene and eugenyl acetate with composition 66.37 %, 15.38 %, 1.97 % and 12.99 %, in clove oil of Toli-Toli and 72.34 %, 12.51 %, 2.34 % and 5.33 %, in clove oil of Bali respectively. The unique minor compounds of clove oil from Toli-Toli were (+)-δ-cadinene (0.13 %) and β-caryophylladienol (0.19 %) while in clove oil from Bali were valencene (0.17 %), δ-selinene (0.22 %) and alloaromadendrene (0.24 %). Thity six compounds were identified from the clove bud oil of Toli-Toli and 38 compounds from the clove bud oil Bali (Sulistyoningrum *et al.*, 2017).

Thirty-six and thirty-four chemical constituents were identified based on GC-MS from clove oil collected from Java and Manado, respectively. Clove Java contained eugenol (55.60 %), eugenyl acetate (20.54 %), caryophyllene (14.84 %), and α-humulene (2.75 %) while, in clove Manado, the composition were eugenol (74.64 %), caryophyllene (12.79 %), eugenyl acetate (8.70 %), and α-humulene (1.53 %). Minor constituents β-elemene (0.04 %), α-cadinene (0.05 %) and ledol (0.06 %) existed only in clove Java, while clove Manado had some unique minor constituents. β-gurjunene (0.04 %), γ-cadinene %), and humulene oxide (0.05 %) which were not found in clove Java. (Amelia *et al.*, 2017).

5.2.4 Incidence of diseases

Leaf spot, leaf rot and die back of the branches were found to be the most common diseases in clove. Among these diseases, leaf spot was noticed in the selected clove accessions but at low level of incidence. Accession AMC-9 which was spotted at Ambanad estate shows little incidence or tolerance to leaf spot disease. Surveys were condssucted in Kanyakumari district by Horticulture research centre, Pechiparai indicated that leaf spot of clove was high in Keeriparai and Pechiparai area (AICRP, 2005).

5.2.5 Incidence of pests

With respect to pest incidence, there was no pest incidence observed in the selected clove accessions.

5.2.6 Quantitative characterization

The principal component analysis is a multivariate statistical technique used to simplify and analyze the inter relationship among a large set of variables in term of a relatively a small set of variables or components without losing any essential information of original data set.

In the present investigation, the principal component analysis of 32 quantitative characters resulted in the first two principal component explaining 88.8 per cent variation (appendix III). The eigen vectors designated as Principal Component-1 and Principal Component-2 with the respective component loadings of all the 32 characters were taken. PCA detected the most important traits for the grouping. PC_1 and PC_2 explained the whole variability in accessions i.e. 88.88 % of the total variance. The most important traits for the separation are those with the biggest loading on PC_1 and PC_2. Characters like tree girth at 45 cm height, single bud weight (fresh) and single bud weight (dry) and number of inflorescence/m^2 were the characters with high positive and negative loadings. The characters which contributed to high variation in first principal component included single bud weight (fresh) (0.87), tree girth at 45 cm height (0.335), and single bud weight (dry) (0.262). In the second principal component, character that contributed to the variation was number of inflorescence/m^2 (-0.959).

According to Mahendran *et al.* (2015), higher the coefficients, regardless of the direction (positive or negative), the more effective they will be in discriminating between accessions. Thus, the prominent characters coming together in different principal components and contributing towards explaining the variability have the tendency to remain together. Hence this may be kept into consideration during utilization of these characters in breeding programme. Characters with high

variability are expected to provide high level of gene transfer during breeding programs (Aliyu *et al.*, 2000: Gana, 2006). Hence selection of clove accessions with these characters may be carried out and these characters provide a room for crop improvement works.

Score plot developed between PC_1 and PC_2 depicted a clear pattern of grouping accessions. Fourteen clusters were identified based on score plot and earmarked in the same figure. The listing of the constituent members of the 14 quantitative clusters are given in the Fig. 2. Clustering based on quantitative characters resulted in Cluster I containing BRC-1, Cluster II containing BRC-2, Cluster III containing BRC-3, Cluster IV containing BRC-4 and MMC-15, Cluster V containing MRC-5 and BLC-16, Cluster VI containing accessions MRC-6, AMC-13, MMC-14 and BLC-17, Cluster VII containing MRC-7 and MRC-8, Cluster VIII containing AMC-9, Cluster IX containing AMC-10, Cluster X containing AMC-11, Cluster XI containing AMC-12, Cluster XII containing BLC-18,Cluster XIII containing MGC-19 , Cluster XIV containing ANC-20. Ten clove accessions remain apart due to certain quantitative characters. Cluster VI contained four clove accessions while Cluster IV, V, and VII contained only two accessions each.

5.2.6.1 Parallelism between qualitative and quantitative clustering

Clustering pattern based on qualitative characters and quantitative characters were different. Qualitative characters of the selected twenty accessions were grouped into thirteen clusters based on dendrogram while quantitative characters were grouped into fourteen clusters based PCA score plot.

Parallelism between qualitative and quantitative characters or association of qualitative and quantitative clusters explains the extent of linkage between the qualitative and quantitative clustering patterns.

A comparison of the two clustering patterns was done by finding out the per cent distribution of accessions of a qualitative cluster over the different quantitative

clusters. Majority of accessions in a single qualitative cluster fall in a single quantitative cluster indicating the similarity among these accessions at quantitative level also.

All the accessions of qualitative Clusters I, IV, V, VII, IX, X, XI and XII were distributed in the quantitative Clusters I, VII, XI, V, XIII, XIV, III and VIII respectively. Only single accessions belonged to this clusters.

The accession in the qualitative Cluster III were found to be equally distributed in the quantitative Clusters VI & XII. Similarly, the accessions in the qualitative Cluster VI in quantitative Cluster V and VI, XII were also found to be equally distributed in VI and X.

Accessions in qualitative cluster VIII were equally distributed through the quantitative cluster VI, VII and IX.

In the case of qualitative cluster II, 33.33 per cent of the accessions fell in quantitative cluster II and 66.67 per cent in IV.

5.2.6.2 Perceived quantitative characterization

Perceived quantitative characterisation was undertaken to understand how far the quantitative characters were distributed with the qualitative character. By assessing this, one will be able to identify the character required for suitable selection. For clusters in which the accessions were evenly distributed, the average of the quantitative character was taken. For clusters in which the accessions were not evenly distributed, the weighted average of the quantitative character was taken, weighted average being the distribution of individual members over the quantitative clusters. Perceived quantitative characterisation was undertaken for 32 quantitative characters.

5.2.6.3 Linkage between major quantitative characters of clove

The linkage was analysed based on the biplot of Principal Component scores of the characters. This biplot is justifiable by the fact that the first two principal component explained 88.8% of variation.

The correlation coefficient between any two characters is estimated by the cosine of the angle between their vectors (Yan and Rajcan, 2002). The correlation coefficients among the quantitative traits with relatively large loadings on PCA1 or PCA2 axis were high. The linkage analysed based on the biplot of Principal Component scores revealed a strong positive association between all quantitative characters measured except, girth at 45 cm height, number of branches, number of inflorescence/m^2, single bud weight (fresh), single bud weight (dry) and fresh bud yield per tree.

A near zero correlation was observed between number of inflorescence per m^2 and single bud weight (fresh) and single bud weight (dry) as indicated by near perpendicular vectors. Biplot analysis between PC_1 and PC_2 axis revealed that vector C_{15} (single fresh bud weight) was the longest. Second in magnitude was C_9 (number of inflorescence /m^2) with positive loadings for PC_1 and negative loadings for PC_2. If a character has a principal component score of near zero it has small interaction effects and is considered as stable. Thus, characters except C_{15}, C_9, C_{20}, C_2, C_5, C_{16} all others have short spokes and they do not extent any strong interactive force. Those characters with long spokes exert strong interaction.

5.2.6.4 Minimum Data Set (MDS) characters

The selection of representative Minimum Data Set (Doran and Parkin, 1994) was done by the Principal Component Analysis (PCA) based on the assumption that principle components receiving higher values best represent the system attributes. Among each principal component, the one with the highest sum of correlation coefficients was chosen for the MDS.

The minimum data set for identifying a promising clove accession were generated based on the values of the component loadings of the first two Principal Components, that explained 88.8% of the total variation. The data generated consisted of a vector and a singleton characteristic. The vector of characteristics were girth at 45 cm height, single bud weight (fresh) and single bud weight (dry). The singleton characteristics constituted as number of inflorescence/m^2.

5.2.6.5 Illustration of identification of an ideotype using existing data

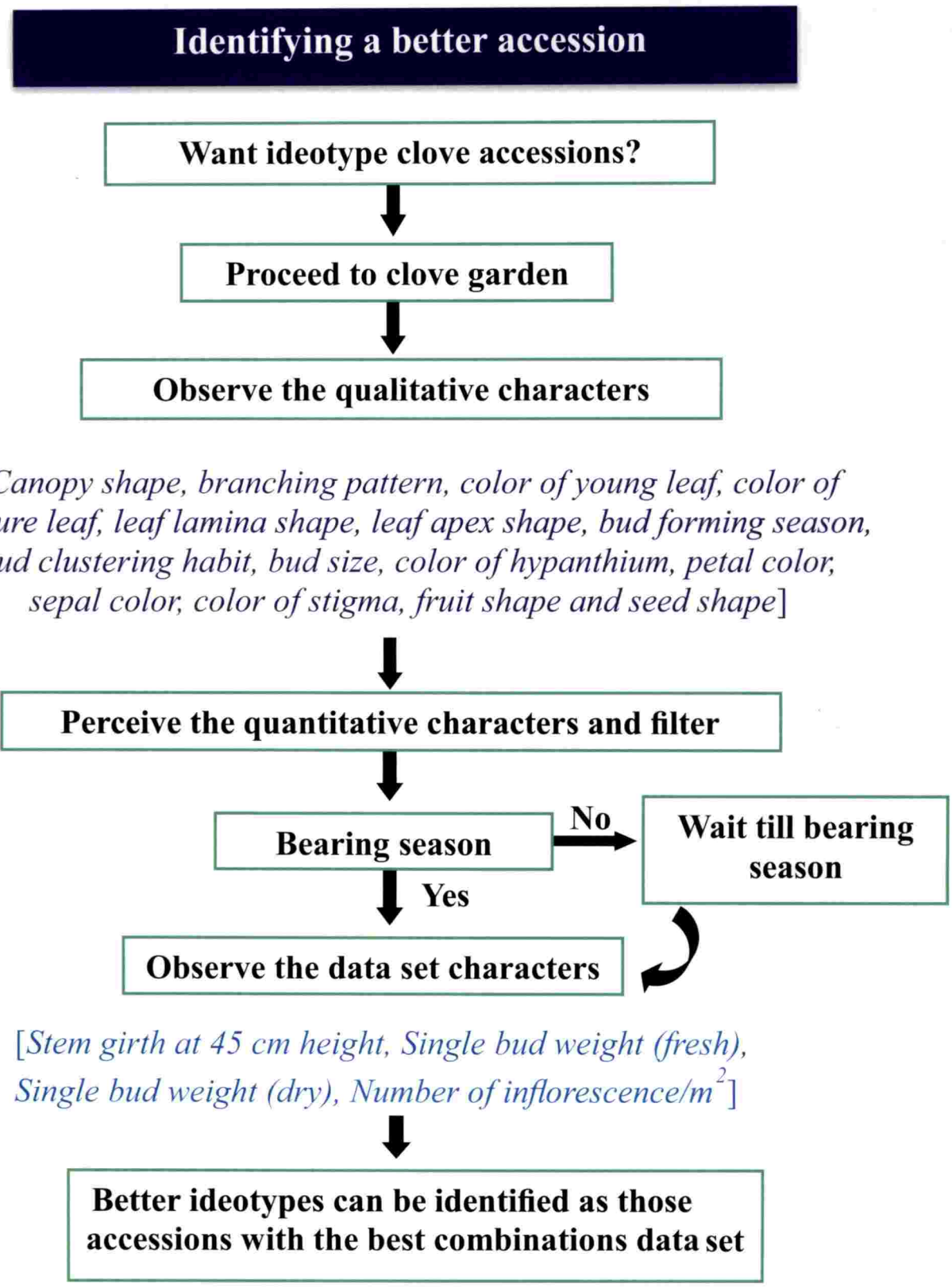
Analysis of the existing data revealed that accessions BRC-1, MRC-5, and MRC-6 had better ideotype and can be suggested as elite accessions. BRC-1 had 118.5 cm stem girth at 45 cm height, 327.05 g the single bud weight (fresh), 114 g the single bud weight (dry) and the number of inflorescence/m^2 as 114. The effective yield worked out was 175.08 g/m^2 which was a higher yield. Similarly, MRC-5 and MRC-6 also had a stem girth of 90.7 cm at 45 cm height, single bud weight (fresh) and single bud weight (dry) as 96.55 mg and 16.63 mg respectively. The number of inflorescence/m^2 was 83.87 and the effective yield was 134.66 g/m^2.

BRC-3 could also be considered as a superior or elite accession because it satisfies all existing data set characters with high value except number of inflorescence/m^2. BRC-3 had 138.1 cm stem girth at 45 cm height, single bud weight (fresh) as 400.37 g, single bud weight (dry) as 128.5 g and number of inflorescence/m^2 as 73.75. All the characters except the number of inflorescence/m^2 were higher in BRC-3. The less number of inflorescence might be due to the less nutrient availability especially low K nutrient status as revealed from the table 5. Moreover, the accession which was located in congested shady area might also have resulted in less yield.

5.2.6.5.1 Identification of a better accession

The parallelism between the qualitative and quantitative characterisation yielded in the projection of the quantitative characters based on the major qualitative characters. Thus, an investigator shall first identify a clove tree that

possesses a desirable set of qualitative characters and the quantitative characteristics should be mapped accordingly. In the bearing season the minimum data set characters should be observed This will optimally sort out ideotype for clove accessions.


Identifying a better accession
Want ideotype clove accessions?
Proceed to clove garden
Observe the qualitative characters
[Canopy shape, branching pattern, color of young leaf, color of mature leaf, leaf lamina shape, leaf apex shape, bud forming season, bud clustering habit, bud size, color of hypanthium, petal color, sepal color, color of stigma, fruit shape and seed shape]
Perceive the quantitative characters and filter
Bearing season
No
Wait till bearing season
Yes
Observe the data set characters
[Stem girth at 45 cm height, Single bud weight (fresh), Single bud weight (dry), Number of inflorescence/m2]
Better ideotypes can be identified as those accessions with the best combinations data set

SUMMARY

6. SUMMARY

Survey was carried out in the major clove growing regions of Trivandrum, Kollam and Pathanamthitta districts of Kerala and Kanyakumari district of Tamil Nadu for characterisation of clove accessions and to identify superior high yielding type during the period from 2016-2018.

Twenty accessions from seven clove growing plantations were identified and named as BRC-1, BRC-2, BRC-3, BRC-4, MRC-5, MRC-6, MRC-7, MRC-8, AMC-9, AMC-10, AMC-11, AMC-12, AMC-13, MMC-14, MMC-15, BLC-16, BLC-17, BLC-18, MGC-19 and ANC-20. Passport data of selected clove accessions were collected. Twenty selected clove accessions were observed for their qualitative and quantitative characters and yield for two years viz., 2016-17 and 2017-18. Soil N, P, K, organic carbon and soil pH were recorded in the selected clove accessions and nutrients were applied based on the soil test data as per the package of practices of Kerala Agricultural University.

Twenty selected clove accessions were observed for qualitative characters which included tree, leaf, bud, flower, fruit and seed characters. Considerable variation was present among the accessions for 15 out of 21 qualitative characters observed. Characters like leaf arrangement, position of flower, colour of peduncle, mature fruit colour, ripe fruit colour and seed colour were non variable characters among the accessions and were not included for further analysis.

In the tree characters evaluated, elliptical canopy shapes were observed in 40% of the accessions followed by cylindrical (20%), conical (20%) and pyramidical shapes (20%). Semi-erect branching pattern was common (55%) followed by irregular (35%) and erect (10%). The colour of young leaf among the selected and evaluated accessions were red pink with light green tinge in 85 %, followed by yellow green with light green tinge (10 %) and purple red with light green tinge in 5 % while that of mature leaf was dark green (65%) and the rest were green (35%).

The predominant leaf lamina shape was lanceolate with acuminate leaf apex (85%) followed by narrowly elliptical leaf lamina with acute leaf apex (15%).

Bud forming season of the selected accessions was classified as early, mid and late season of which mid-season was the predominant. Majority of the accessions were having combination of 1,2,3 flower buds per cluster (85%) while the rest had combination of 1,2,3,4,5 flower buds per cluster. Medium sized buds were reported from 70% of the accessions followed by large (20%) and small (10%). The predominant hypanthium colour was light red pink (95%) while only one accession, AMC-9 exhibited dark purple red.

The flower consisted of petals of light green with pinkish tinge colour and sepal of yellow green with light green stigma in all the accessions except one accession which had green brown petals with dark purple red sepal colour and yellow green stigma. The shape of the fruit and seed obtained was oblong in 85% and elliptic in 15 %.

Bivariate analysis of major qualitative characters revealed that when canopy shapes were elliptical majority of the plants were having semi-erect branching pattern (54.54%). Similarly, when colour of young leaves were red pink with light green tinge majority of the accessions were having light green petal (89.47%) and when colour of young leaves were red pink with light green tinge majority of the accessions were having yellow green sepal (89.47%). Colour of young leaves when it was red pink with light green tinge majority of the accessions were having yellow light green stigma (89.47%). The medium sized bud (64.29 %) was associated with dark green leaf. However, seed shape was evenly distributed with respect to the fruit shape.

Association of characters like canopy shape with bud clustering habit, bud size, fruit shape and seed shape; branching pattern with bud clustering habit, bud size, fruit shape and seed shape; colour of young leaf with bud clustering habit, bud size, fruit shape and seed shape; colour of mature leaf with fruit shape, seed shape, petal colour, sepal colour and colour of stigma; leaf apex shape with bud clustering

habit, fruit shape and seed shape; leaf lamina shape with bud clustering habit, fruit shape and seed shape were found to be non significant.

According to Unweighted Pair Group Method with Arithmetic Mean hierarchical techniques twenty accessions were grouped into 13 clusters based on qualitative traits at 80 % similarity. Cluster II and VIII had 3 accessions while cluster I, IV, V, VII, IX, X, XI and XIII had only single accessions. Among the thirteen clusters, Cluster I included BRC-1, Cluster II included BRC-2, MMC-15 and BRC-4, Cluster III contained MMC-14 and BLC-18, Cluster IV with MRC-7, Cluster V contained AMC-12, Cluster VI with MRC-5 and MRC-6, Cluster VII included BLC-16, Cluster VIII contained MRC-8, AMC-10 and BLC-17, Cluster IX contained MGC-19, Cluster X with ANC-20, Cluster XI contained BRC-3, Cluster XII included AMC-11 and AMC-13 and Cluster XIII with AMC-9.

Quantitative characterisation carried out included tree, leaf, bud, flower, fruit and seed characters. The plant height measured between the twenty selected clove accessions ranged from 5.15 m to 15.25 m and the girth at 45 cm height ranged from 44.10 cm to 138.10 cm. The N-S canopy spread was the highest for MRC-7 while the E-W canopy spread was the highest for AMC-11. The number of branches among accessions ranged from 26 to 55. Minimum leaf length in the selected accession measured was 9.66 cm while maximum was 13.93 cm in MRC-5 and the leaf breadth of selected accessions varied from 3.55 cm to 4.72 cm. Leaf area thus calculated varied from 23.07 cm^2 in ANC-20 to 42.93 cm^2 in AMC-11.

The number of inflorescence per m^2 among the accessions varied between 155.5 to 36.25 and the number of flower buds per inflorescence from 6.05 in ANC-20 to 18.21 in MRC-6. The single bud weight (fresh) and single bud weight (dry) was the highest for BRC-3. The single bud weight (dry) ranged from 66.5 to 128.5 g. The mature bud length varied from 14.94 mm to 19.06 mm while the mature bud diameter ranged from 4.9 mm to 6.41 mm. The period taken from bud initiation varied from 103.8 to 118.4 days among the accessions. The pooled mean of bud yield per tree fresh varied from 2.7 to 40.25 kg. BRC-1, MRC-5, MRC-6, MRC-8,

AMC-10 and MMC-15 were good yielders recording more than 30 kg/tree as revealed from pooled mean. The length of flower ranged from 16.36 mm to 21.84 mm and the breadth ranged from 9.85 mm to 14.82 mm. The number of sepal and petal was constant while the length of sepal ranged from 2.49 mm to 3. 15mm.The fruit weight ranged from 1.2 g in ANC-20 to 3.53 g in BRC-3. The ratio of fruit to seed varied between 2.41 to 3.64. The seed length varied from 13.2 to 19.31mm and seed breadth from 6.11 to 9.19 mm in the selected accessions. The seed weight was the highest for BRC-3 (1.18 g). The time taken for harvest of fruits from flowering ranged from 86.8 to 97.6 days. The bud oil in the selected accessions varied from 12.53 to 19.6 % while the stem oil ranged from 3.6 to 6.7 %. The bud oleoresin showed a range from 16.9 to 24.3 % and the stem oleoresin from 7.1 to 12.2%. The eugenol content between accessions ranged between 54.29 and 70.77%. GC MS analysis of the bud oils of the improved clove accessions like BRC-1, BRC-3, MRC-5 and MRC-6 exhibited 25 constituents. The major constituents of the bud oil were p-eugenol, eugenyl acetate, β-caryophyllene, β-cubebene, 4-Quinolinol and α-humulene.

The Principal Component Analysis of quantitative characters resulted in the first two principal component explaining 88.8% variation. A score plot generated based on the first two Principal Components using Minitab version 18 identified fourteen clusters. The linkage analysed based on the biplot of Principal Component scores revealed a strong positive association between all quantitative characters measured except, girth at 45 cm height, number of branches, number of inflorescence/m^2, single bud weight (fresh), single bud weight (dry) and fresh bud yield per tree. Minimum Data Set for identifying a promising clove accession were generated. Based on existing data, accessions BRC-1, MRC-5, and MRC-6 and BRC-3 were identified as ideotypes of clove.

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ABSTRACT

SURVEY, CHARACTERIZATION AND EVALUATION OF CLOVE (*Syzigium aromaticum* (L) Merr. & Perry) ACCESSIONS

by

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Abstract of the thesis

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ABSTRACT

The present study entitled "Survey, characterization and evaluation of clove (*Syzigium aromaticum* (L) Merr. & Perry) accessions" was taken up with the specific objective to characterize and evaluate clove accessions based on morphological and biochemical parameters.

The Survey was carried out in the major clove growing plantations of Trivandrum, Kollam and Pathanamthitta districts of Kerala and Kanyakumari district of Tamil Nadu, as these districts harboured the major clove population. Twenty varied accessions were tagged as BRC-1, BRC-2, BRC-3, BRC-4, MRC-5, MRC-6, MRC-7, MRC-8, AMC-9, AMC-10, AMC-11, AMC-12, AMC-13, MMC-14, MMC-15, BLC-16, BLC-17, BLC-18, MGC-19 and ANC-20 based on the name of the estates/location from where the trees were identified. Twenty one qualitative and thirty four quantitative characters were recorded. Qualitative characters included tree, leaf, bud, flower, fruit and seed characters. Considerable variation was noticed among the accessions for the qualitative characters namely canopy shape, branching pattern, colour of young leaf, colour of mature leaf, leaf lamina shape, leaf apex shape, bud forming season, bud clustering habit, bud size, colour of hypanthium, petal colour, sepal colour, colour of stigma, fruit shape and seed shape. Few characters like leaf arrangement, position of flower, colour of peduncle, mature fruit colour, ripe fruit colour and seed colour were non variable characters among the accessions evaluated. Bivariate analysis of major qualitative characters revealed major association between canopy shape and branching pattern; colour of young leaf and petal colour, sepal colour and colour of stigma; colour of mature leaf and bud size; and fruit shape and seed shape. The multivariate qualitative clustering using UPGMA method resulted in 13 clusters, at default 80% similarity.

Quantitative characterisation of bud, flower, fruit, seed and quality parameters summarised based on the descriptive statistics revealed wider range of variability in number of inflorescence per m^2 and single bud weight fresh and dry.

The quality parameters assessed among the accessions revealed eugenol as the main constituent with a content range of 54.29 to 70.77%. GC MS analysis of the bud oils of the elite clove accessions exhibited 25 constituents, the major being p-eugenol, eugenyl acetate, β-caryophyllene, β-cubebene and α-humulene.

The principal component analysis undertaken reduced the thirty two quantitative characteristics to two principal components accounting for 88.8% of total variation. Stem girth at 45 cm height, and single bud weight, fresh and dry; displayed high correlation with the first axis while number of inflorescence per m^2 highly influenced the second axis indicating that these characters have an important role in clustering of clove accessions. A score plot generated based on the first two principal components using Minitab version 18 identified fourteen clusters. The parallelism between qualitative and quantitative clusters resulted in intuitive perceived quantitative characterisation, which tells the extent to which one can conceive the quantitative characters of clove based on easily identifiable qualitative characters.

The linkage of characters analysed based on the biplot of component loadings revealed strong positive association between all the quantitative characters measured except girth at 45 cm height, number of branches, number of inflorescence per m^2, single bud weight (fresh), single bud weight (dry) and fresh bud yield per tree. A near zero correlation was observed between number of inflorescence per m^2 and single bud weight (fresh) and single bud weight (dry) as indicated by the perpendicular of the vectors.

The results of the study indicated that by observing the qualitative characters and the minimum data set characters in the bearing season, one can optimally sort out the ideotype clove accessions. Identification of an ideotype using existing data revealed accessions BRC-1, MRC-5, MRC-6 and BRC-3 as ideotypes and thus can be suggested as elite accessions for further study and breeding work.

APPENDICES

APPENDIX I

FERTILIZER RECOMMENDATION IN CLOVE AS PER RECOMONDATION OF KERALA AGRICULTURAL UNIVERSITY PACKAGE OF PRACTICES (0.3: 0.25: 0.75 kg tree^{-1} year^{-1})

Soil fertility class	N (kg palm^{-1})	Urea (kg)	P_2O_5 (kg)	Rajphos (kg palm^{-1})	K_2O (kg)	MOP (kg)
0	0.384	0.834	0.320	1.777	0.960	1.60
1	0.351	0.763	0.292	1.622	0.877	1.462
2	0.318	0.691	0.265	1.472	0.795	1.325
3	0.291	0.632	0.235	1.305	0.705	1.175
4	0.273	0.593	0.207	1.150	0.622	1.037
5	0.252	0.547	0.177	0.983	0.532	0.886
6	0.234	0.508	0.150	0.833	0.450	0.750
7	0.213	0.463	0.120	0.666	0.360	0.60
8	0.189	0.410	0.092	0.511	0.277	0.462
9	0.162	0.352	0.062	0.344	0.187	0.312

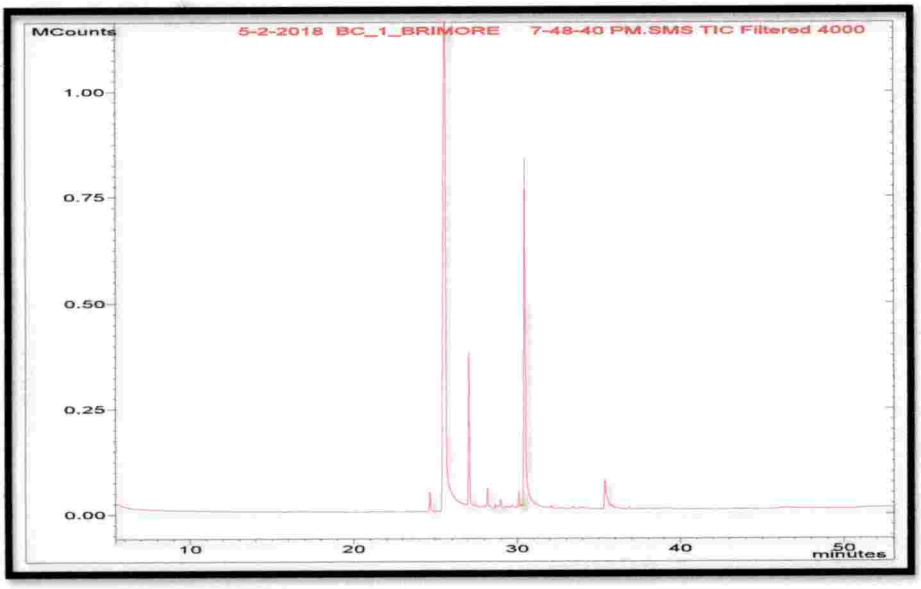
APPENDIX II

QUANTITY OF NUTRIENTS APPLIED IN THE SELECTED CLOVE ACCESSIONS

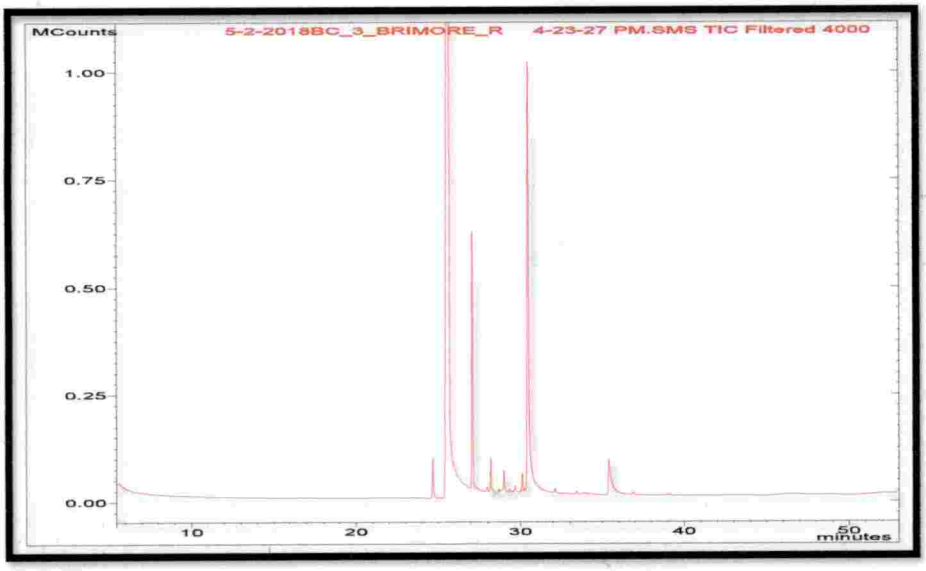
Sl. No.	Accessions	Urea		Rajphos		Murate of Potash	
		Applied rate (kg tree^{-1})		Applied rate (kg tree^{-1})		Applied rate (kg tree^{-1})	
		Full dose	Split dose	Full dose	Split dose	Full dose	Split dose
1	BRC1	0.632	0.316	1.622	0.811	0.750	0.375
2	BRC2	0.352	0.176	1.472	0.736	0.462	0.231
3	BRC3	0.508	0.254	1.150	0.575	0.886	0.443
4	BRC4	0.410	0.205	1.472	0.736	0.750	0.375
5	MRC5	0.691	0.356	1.472	0.736	0.600	0.300
6	MRC6	0.547	0.274	1.622	0.811	0.750	0.375
7	MRC7	0.508	0.205	0.833	0.417	0.600	0.300
8	MRC8	0.547	0.274	1.472	0.736	0.886	0.443
9	AMC9	0.463	0.232	1.150	0.575	0.132	0.066
10	AMC10	0.352	0.176	0.666	0.333	0.462	0.231
11	AMC11	0.352	0.176	0.344	0.172	0.600	0.300
12	AMC12	0.352	0.176	0.833	0.417	0.462	0.231
13	AMC13	0.463	0.232	1.622	0.811	0.600	0.300
14	MMC14	0.352	0.176	1.472	0.736	1.037	0.519
15	MMC15	0.352	0.176	1.305	0.653	1.175	0.588
16	BLC16	0.410	0.205	1.305	0.653	0.886	0.443
17	BLC17	0.410	0.205	1.472	0.736	0.750	0.375
18	BLC18	0.410	0.205	1.472	0.736	0.886	0.443
19	MGC19	0.508	0.205	1.622	0.811	0.750	0.375
20	ANC20	0.547	0.274	1.305	0.653	1.175	0.588

APPENDIX III

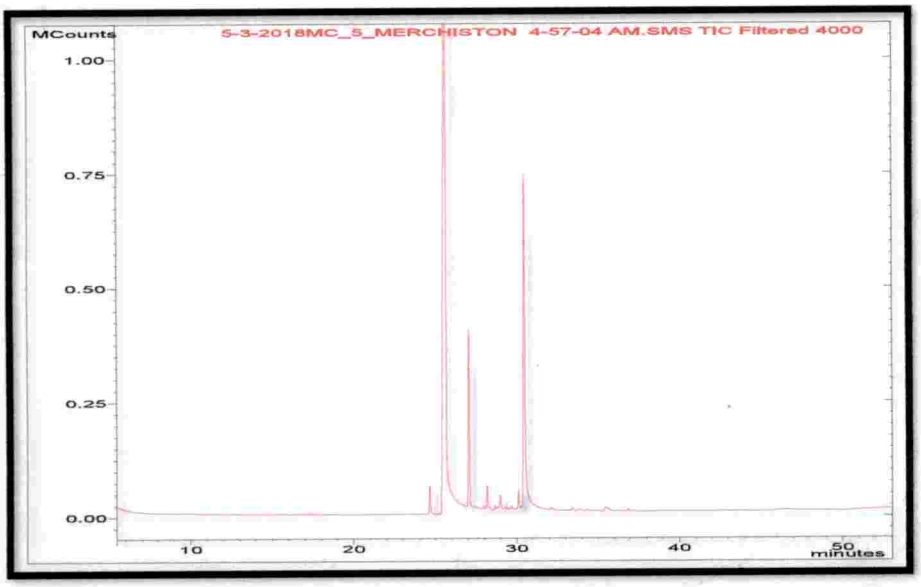
CHROMATOGRAM OF BUD OIL OF SELECTED CLOVE ACCESSIONS



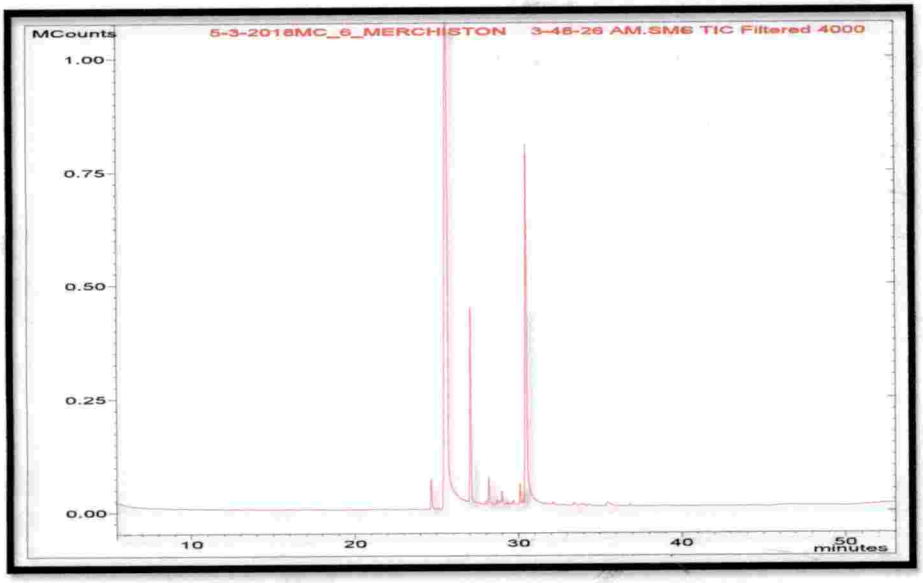
A1. GC MS Profile of bud oil of accession BRC-1



A2. GC MS Profile of bud oil of accession BRC-3



A3. GC MS Profile of bud oil of accession MRC-5



A4. GC MS Profile of bud oil of accession MRC-6

APPENDIX IV: PRINCIPAL COMPONENT ANALYSIS

Sl. no.	Eigenvalue	Proportion	Cumulative
1	2827.7	0.659	0.659
2	980.6	0.229	0.888
3	263	0.061	0.949
4	84.9	0.02	0.969
5	46.7	0.011	0.98
6	26.7	0.006	0.986
7	19.1	0.004	0.99
8	15.6	0.004	0.994
9	10.8	0.003	0.996
10	6.1	0.001	0.998
11	2.6	0.001	0.998
12	2	0	0.999
13	1.3	0	0.999
14	1.2	0	1
15	0.9	0	1
16	0.5	0	1
17	0.3	0	1
18	0.1	0	1
19	0	0	1
20	0	0	1
21	0	0	1
22	0	0	1
23	0	0	1
24	0	0	1
25	0	0	1
26	0	0	1
27	0	0	1
28	0	0	1
29	0	0	1
30	0	0	1
31	0	0	1
32	0	0	1