EVALUATION OF ROSE VARIETIES FOR COMMERCIAL CULTIVATION UNDER THE WARM HUMID TROPICS OF KERALA

By

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(2016-12-009)

THESIS

Submitted in partial fulfilment of the

requirements for the degree of

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2018

DECLARATION

I, hereby declare that the thesis entitled **"Evaluation of rose varieties for commercial cultivation under the warm humid tropics of Kerala"** 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 to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

Vellanikkara
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CERTIFICATE

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Priya Philip

Dedicated to

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF PLATES

LIST OF FIGURES

LIST OF APPENDICES

Appendix No.	Title
I	Biweekly observations on vegetative characters in cut flower varieties
II	Biweekly observations on vegetative characters in loose flower varieties
III	Meteorological data during the period of observation from September 2017 to March 2018 inside and outside polyhouse

LIST OF ABBREVIATIONS AND SYMBOLS USED

Symbols	Abbreviations
et al.	And others
cm	Centimetre
CRD	Completely Randomized Design
CD	Critical difference
cv.	Cultivar
^{0} C	Degree Celsius
Fig.	Figure
GAM	Genetic advance as percent of mean
GCV	Genotypic coefficient of variation
g	Gram
ha	Hectare
IIHR	Indian Institute of Horticultural Research
kg	Kilogram
m	Metre
MT	Metric Tons
ml	Millilitre
MAP	Months after planting
NS	Non- Significant
%	Per cent
PCV	Phenotypic coefficient of variation
sp. or spp.	Species (Singular and Plural)

Introduction

1. INTRODUCTION

Floriculture, the colourful sector of horticulture is being identified as a lucrative business, generating income and employment to thousands of people. In India it is a dynamic and expanding industry having an annual growth rate of 20 per cent. The flower crops in India cover an area of 309 ha and a production of 593,000 MT of loose flowers and 1653,000 MT of cut flowers. Among the different flower crops grown in India, rose is the principal flower crop grown all over the country which covers an area of 29,410 ha with a production of 301,950 MT. The export of roses from India was 3,000 MT with a value of 141.45 lakh (AC & FW, 2017).

Rose (*Rosa* spp.) globally designated as "Queen of flowers" due to its diversity and elegance in colour, grace and fragrance, ranks first among the top ten cultivars in the international market. The word Rose is originated from the Greek word "*Rhedon*" meaning excellent fragrance. It symbolises love, joy, innocence, friendship and purity and admired as the national flower of USA, England, Iran, Maldives and Bulgaria.

Rose is a flowering perennial plant with size ranging from miniatures, shrubs, standards and climbers. It belongs to the genus Rosa and family Rosaceae and having a chromosome number of n = 7. There are about 200 species in this genus and 18000 cultivars (Gudin, 2000) with exquisite shape, size, and fragrance which made it an important flower for varied uses.

Cut roses along with long stalk are mainly used in bouquets, flower arrangements, interior decorations, social and religious functions and for dry flower making whereas loose flowers are used for making garlands, edible products, cosmetics and as offerings. In Indian floriculture industry, roses accounts for 65 per cent of total demand of flowers. There is a high demand for Indian roses in international market and local demand is also growing up especially in cities. Novel types of cut flowers and loose flowers having improved growth, yield and quality attributes are always in demand. The research on roses should be prioritized for the

development of long-stalked, good coloured and pest and disease resistant varieties with focus on cost reduction in greenhouses and market intelligence to enhance the productivity of rose cultivation (Sivaramane *et al*., (2008).

Climatic factors play a critical role for successful production of roses. Ideal temperature for rose production is 20-25^{0}C during day and 13-16^{0}C during night with 8 hours of sunlight. In Kerala, rose cultivation under open is mainly confined to districts like Idukki and Wayanad due to the favourable agro climatic conditions in these regions. High temperature and relative humidity prevailing in the plains of Kerala make these regions unsuitable for rose cultivation under open. However, naturally ventilated poly houses can be successfully utilized in the plains of Kerala for commercial production of cut flowers as well as loose flowers. So, in the current situation, there is a need to identify rose varieties suitable as cut flower and loose flower for poly house cultivation in Kerala. Hence, the study is proposed with the following objectives

1) To evaluate the performance of cut flower and loose flower rose varieties under polyhouse

2) To select suitable varieties of cut flower and loose flower types for commercial cultivation in the plains of Kerala.

17

Review of literature

2. REVIEW OF LITERATURE

Rose is most popular among all flowers due to its exquisite shape, unique colour and delightful fragrance. It is grown for versatile purposes such as cut flower, loose flower, for the production of value added items and as a garden plant in landscapes. Modernisation and changing life style had made a drastic increase in demand for fresh flowers of rose as well as its value added items in Kerala. Even though roses are adapted to cooler climate, certain varieties can withstand warm humid tropical climate. There is a great potential for cultivation of roses under naturally ventilated polyhouses in warm humid climates. Literature pertaining to varietal evaluation, effect of meteorological parameters on growth and yield and protected cultivation of rose and other flower crops are reviewed here under.

2.1. VARIETAL EVALUATION

Information regarding performance of a variety in a particular region with respect to growth habit, yield and quality parameters plays a major role in selection of varieties for commercialisation.

2.1.1. Rose as cut flower

Ichimura *et al.* (2002) evaluated twenty five rose cultivars for vase life and the variety 'Calibra' was found to be superior with respect to this parameter. Tabassum *et al.* (2002) evaluated ten rose varieties and the varieties 'Alexandria' and 'Paradise' were recommended for outdoor beautification due to larger flower size and the variety 'Freesia' was recommended for cut flower purpose.

Performance evaluation of different rose varieties revealed the suitability of varieties 'Arjun' and 'Super' Star for commercial cut flower production as these varieties had highest marketable yield per bush (Dias and Patil, 2003). Polara *et al.* (2004) evaluated nineteen hybrid tea cultivars and ten floribunda cultivars in summer months under Saurashtra conditions and reported that the cultivars 'Eiffel Tower' in

hybrid tea group and 'Dickson`s Flame' and 'Zorina' in Floribunda group gave better performance in summer under South Saurashtra conditions of Gujarat.

Nine cut rose varieties were evaluated for their cut flower production and consumer acceptance under dry highland and the variety 'Periwigo' was found to be superior in terms of vegetative parameters, variety 'Akito' had highest number of flowers whereas the varieties 'Grand Gala' and 'Tineke' were superior in terms of flower quality parameters (Purbiati and Santoso, 2007).

Sloan *et al.* (2008) evaluated seventeen cultivars for their cut flower potential based on the number of flower stems and stem length and reported that the varieties 'Frederic Mistral', 'Michelangalo', 'The Mc Cartney Rose' and 'Traviata' with 30 cm stem length as best cultivars which produced 3-20 stems per plant per month. Thirteen greenhouse rose cultivars were evaluated for their performance under open field conditions and maximum number of flowers per plant (208.6), flower yield per plant (1.29 kg) and marketable flower yield (12.34 ton /ha) were reported in variety 'Avalanche' (Harshawardhan, 2009).

A study conducted to compare the growth and yield of five cut rose varieties and revealed that that the varieties 'Rosy Cheeks' and 'Whisky Mac' had vigorous vegetative growth while 'Amalia' and 'Anjilique' produced higher flower yield of best quality and identified as best cultivars for commercial production (Ahmed *et al.*, 2011).

An evaluation study to test the suitability of hybrid tea rose varieties to hot tropical conditions revealed that the varieties 'Autumn Sunset 'and 'Gruss an Teplitz' performed well under tropical conditions (Nadeem *et al.*, 2011).

Peng *et al.* (2012) evaluated six floribunda rose cultivars and reported that the varieties 'Beijinghong and 'Purple meidilan' were best for cut flower purpose.

Thirty floribunda roses were evaluated under subtropical climate and observed that the variety 'Banjaran' had the maximum plant height whereas other vegetative parameters like plant spread, leaf length and leaf breadth were highest in variety 'Brown Velvet'. Even though the variety 'Summer Snow' produced maximum number of flowers per unit area; the varieties 'Charleston', 'Arunima' and 'Brown velvet' were superior in terms of flower size, number of petals and stalk length respectively (Singh *et al.*, 2013).

Islam (2013) evaluated phenotypic and ornamental attributes of twelve rose genotypes and maximum plant height and leaf area were observed in variety 'Living Easy'. The shortest time for flowering was taken by 'Wild Blue Yonder' and 'Julie Child'. Maximum number of flowers per plant was produced in variety 'Living Easy' and maximum vase life was reported in variety 'Let Freedom Ring'. Considering the overall ornamental traits the varieties 'Tropicana', 'Let Freedom Ring' and 'Living Easy' were recommended for cut flower purpose.

Performance evaluation of fifteen rose varieties for cut flower purpose revealed that the variety 'Maid of honor' was superior in terms of plant height. Plant spread was maximum in variety 'Bellisima'. The variety 'Gladiator' produced maximum number of flowers per plant with highest flower diameter, stalks length and maximum number of petals and reported as a variety highly suitable for cut flower purpose (Janaki, 2013).

Among the twelve rose varieties evaluated for cut flower purpose the variety 'Kurab Muang', 'Leung Chomp' and 'Mary Rose' had the highest growth rate and earliest flowering and quality flowers were noticed in the variety 'Kurab Muang' (Kajonphol and Sangsiri, 2014).

Nineteen exotic cultivars of hybrid tea roses were evaluated under tropical warm climate and the varieties 'Double Delight', 'Signature', 'Honey Perfume' and

'Pink Peace' were found to perform well during the hot months of May to July (Ramzan *et al.*, 2014).

Ranchana *et al.* (2014) reported that the highest plant height , stem length, neck length, flower diameter, number of petals per flower, number of cut stems per square meter, vase life and minimum days to sprouting and days to flowering were observed in variety 'Passion' when ten varieties were evaluated for cut flower purpose.

Santagostini *et al.* (2014) evaluated rose varieties and reported the variety 'Meiburenac' as a highly floriferous variety with a yield of 105 flowers per plant in green house and 213 flowers per plant under open. The diameter of flower was found to be significantly higher for 'Starina' and 'Meiburenac' varieties.

The performance evaluation and categorisation based on colour, fragrance and use of forty-four rose cultivars was carried out by Shahrin *et al.* (2015) and reported that vegetative parameters like number of shoots per plant, number of leaves per 10 cm shoot and leaf area were maximum in varieties 'Anindo kun hazari','Red baby' and Sleepy moon' respectively. The variety 'Aranchan' produced maximum number of flowers per plant whereas the variety 'Chrysanthemum rose' was superior in terms of number of petals per flower. Based on the overall performance, the varieties 'Taj Mahal', 'Yellow Star', 'Lavender Gold, 'Compassion', 'SAU hero', 'Yellow Gold', 'Sleepy Moon', 'Sweet Doll', 'Chrysanthemum rose' and 'Sweet Sakata' cultivars were reported to be the best for cut flower purpose.

Results of the study to evaluate the yield and quality of different rose cultivars revealed that the variety 'Sugandha' had maximum number of flowers per plot and flowers per ha and quality parameters like flower diameter and vase life. Variety 'Dr. M. S. Randhawa' recorded maximum number of petals per flower whereas highest fresh weight of flower as well as weight of petals was recorded by variety 'Kumkum' (Wasnik *et al.*, 2015).

Genotypic evaluation of miniature, polyantha and floribunda roses were carried out by Dandhwal, (2016) and reported that the polyantha cultivar 'Majority Fair' had highest plant height, plant spread, number of branches flower bud length, flower longevity, days to flowering, number of lowers per plant and duration of flowering while the miniature cultivar 'Centre Piece' had highest flower diameter.

An evaluation study conducted by Gogoi *et al.* 2016 for various vegetative and floral traits on ten genotypes of roses revealed that variety 'First Red' exhibited better vegetative, floral and physiological characteristics *viz.* plant height, intermodal length, stem girth, bud length, stalk length, flower diameter, number of petals per flower and vase life. Joshna and Sarkar (2018) reported that the hybrid tea rose varieties 'Bordo', 'First Red', 'Varcelia', 'Mandelon' can be recommended as promising cut flower varieties as these varieties were superior in terms of flower yield and flower quality parameters.

2.1.1. Rose as loose flower

Four rose cultivars namely *R. damascena* 'Gulqandi', *R. centifolia* 'Sahiwal', *R. borboniana* 'Lahori' and *R. hybrida* 'Gruss an Teplitz' were evaluated with respect to their floral characteristics under Faisalabad agro-climatic conditions in Pakistan. *R. centifolia* 'Sahiwal' was reported as the variety with greatest potential for commercial production as it was having highest floral yield, extended blooming period and high quality essential oil content with high recovery (Younis *et al.,* 2009).

The essential oil content, constituents and morphological and phonologic characteristics of twenty five varieties, chemotypes and hybrids belonging to four *Rosa* spp. (*R. damascene* Mill.,*R. gallica*, *R. centifolia* and *R. alba*) were evaluated by Kovatcheva *et al.* (2011) and highest essential oil content was observed in *R. damascena* accession Svejen 74.

Eight cultivars of *R. damascena* were evaluated for their variability in essential oil content and reported that rose oil produced in Dehradun region of Uttarakhand compete with ISO standard amount of citronellol and nerol (Chauhan *et al.*, 2012). Kumar *et al.* 2014 evaluated five R. *damascena* varieties namely 'Indica', 'Jwala', 'Super jwala', 'Himroz' and 'Hot himroz' and one accession of *R. bourboniana* in western Himalayas for essential oil content and composition. Highest oil content was observed in 'Super Jwala' variety of *R. damascena*.

Olubode *et al.* (2015) conducted an evaluation study to determine the flowering pattern and yield determinants of two hybrid cultivars 'Immaculate' and 'P.H. Baby' in response to seasonal variations under rainfed conditions. The results shown that the variety 'Immaculate 'had better vegetative growth in terms of plant height and number of leaves whereas variety 'P.H. Baby' produced more number of flowers. Nasri *et al.* (2016) evaluated twelve damask rose genotypes and the result showed that the genotypes, 'Kurdistan 3' and 'Kurdistan 2' can be introduced as superior genotypes as both these varieties had better quality characteristics.

2.1.3. Protected cultivation

The effect of green house cover and shading on rose yield was studied by Fonseca and Hanan (1987) and reported a yield of 76.7 flowers per plant over a period of 15.5 months when grown under a double layered polyvinyl chloride structure. Ramesh and Kumar (2000) reported maximum plant height, plant spread and more number of A grade flowers in rose variety 'Raktagandha' grown under 25 per cent summer shading and polythene covering whereas plants kept under 50 per cent shade and polythene covering had maximum number of flowers per plant.

Influence of different levels of pruning on the growth and flowering of rose cultivars under greenhouse condition were evaluated by Jadhav *et al.* (2003) and reported that the cultivar 'First Red' produced buds with maximum length (2.3 cm), bud diameter (2.86 cm), maximum number of leaves per shoot (22.09) and minimum number of days (32.08) for harvest. The performance evaluation of rose variety

'Gladiator' under two production systems *viz.* open field and fan and pad cooled house revealed that the plants under greenhouse produced more number of flowers with highest average stalk length and fresh weight of flower (Patil *et al.,* 2003) An improvement in yield up to 50 per cent and quality of rose were reported by Mara and David, (2003) when grown under smart light based green house.

Mandhar and Carolin, (2004) reported a yield of 160 flowers per m^2 per year when roses were grown under a naturally ventilated poly house of dimension 32 x 6 x 3.5 m.

The performances of four commercial cut flower roses 'Konfetti', 'Novajo', 'Grandprin' and 'Raktagandha' under unheated poly house were evaluated by Sindhu and Kumar (2004) and reported maximum flower size (7.15 cm) and number of petals per flower (21.60 cm) in variety 'Grandprin'. Maximum flowers per m^2 was produced by 'Novajo' (10.42) followed by 'Raktagandha'. The roses grown under naturally ventilated polyhouse and fan and pad cooling were evaluated by Teital *et al.* (2007) and reported that plants in the fan and pad appeared more robust than in the naturally ventilated polyhouse. The stem length was higher in fan and pad method (43.4 cm) than in naturally ventilated poly house (38.7 cm). Ranpise *et al.* (2008) noticed a yield improvement in twenty three rose varieties when grown under poly house conditions.

Manjula (2005) studied the performance of ten rose cultivars under naturally ventilated polyhouse and found that cultivar 'Tineke' recorded maximum number of cut flowers per plant (27.84). Maximum bud length, bud diameter and neck length were reported in 'Grand Gala' whereas 'Ravel' showed maximum shoot girth and 'Sky Line' recorded maximum neck girth. The longevity of cut flowers held in tap water was maximum in 'Grand Gala'.

Six exotic rose varieties namely 'Miracle','Polo', 'Passion', 'Sweetness', 'Sky Line' and 'First Red' were evaluated by Mantur *et al.* (2005) under naturally ventilated polyhouse and significantly higher number of flowers were recorded in the

variety 'Sweetness' (114.50/m^2). Variety 'Polo' had highest stem length (64.18cm) while the flower diameter was significantly higher in 'First Red' (2.62 cm).

Comparative performance of four rose varieties growing under open and protected environment were investigated by Mohanty *et al.* (2011) and reported that the variety 'Montezuma' performed very well with respect to vegetative characters like plant height (60.94 cm), number of laterals (6.69) and plant spread in N-S (53.72 cm) and E-W (35.60 cm) direction. Variety 'Gladiator' was found to be superior in terms of floral characters *viz.* stem length (30.61 cm), flower bud size (3.54 cm), bud diameter (3.52 cm) and number of petals per flower (44.37). Paramagoudar *et al.* 2014 reported highest number of shoots (3.46), number of flowers per plant per year (28.26) and number of petals per flower in variety 'Naranga' and stalk length (63.03 cm), bud length (4.03 cm), bud diameter (3.1 cm) and vase life (8.44 days) in variety 'Grand Gala' when ten varieties of rose were evaluated under naturally ventilated polyhouse.

Evaluation of forty two hybrid rose varieties suitable for Nagpur conditions based on morphological, yield and yield contributing parameters was carried out by Atram *et al.* (2015) and maximum plant height and inter nodal length (6.8) were recorded in variety 'Chardoney'. Maximum number of flowers per plant (45.5) was reported in variety 'Alliance'. Morphological characters were found to be highest in 'Chardoney', 'Alliance', 'Kentucky', 'Derby', 'Roter Champagner', 'Montreal and 'Melody. The varieties 'Alliance, 'Melody, 'Roter Champagner, and 'Melame were superior with respect to yield.

Hosur *et al.* 2015 evaluated the performance of dutch roses under naturally ventilated polyhouse and reported that varieties varied widely in their quality parameters. The variety 'Samurai' recorded highest stalk length, vase life, consumer acceptability, minimum days to bud initiation and harvest while highest number of flower stalk per plant, flower diameter and number of petals per flower was reported in variety 'Tineke'.

The adaptability of rose varieties for moderate high temperature and partial shade in a replicated greenhouse in Mid Country Wet Zone (MCWC) and Intermediate zone (MCIZ) of Srilanka was evaluated by Rupasinghe *et al.* (2015) and the varieties 'Black Magic' and 'White success' were identified to be more adoptable to warm and humid greenhouse conditions in MCWC and MCIZ with respect to plant growth and flower yield. Cut flower varieties 'Grand Gala' and 'Peach Pope' showed longer shelf life compared to 'Black Magic' and 'White Success'.

Shivaprasad *et al.* (2016) evaluated ten rose varieties under naturally ventilated polyhouse and reported that the variety 'Grand Gala' was superior in terms of flower quality and yield attributes like stalk length (66.75 cm), stalk girth (0.96 cm), flower bud diameter (3.91 cm) and vase life (9.22 days). Highest numbers of petals per flower were observed in variety 'Tineke' (37.37 cm), and highest number of flowers per plant (3.58) reported in variety 'Taj Mahal'.

2.2. EFFECT OF METEOROLOGICAL PARAMETERS ON GROWTH AND FLOWERING OF ROSE CULTIVARS

2.2.1. Temperature

According to Mortensen and Moe (1992), the stem length in rose is negatively affected by higher night temperature than day temperature. Dielman *et al.* (1998) observed accelerated bud break in rose under conditions of high irradiance level, high air and soil temperatures.

According to Jawaharlal *et al.* (1999) large sized flowers were produced in rose at optimum conditions of 15-21 ^{0} C mean temperature, 55-80 per cent relative humidity and 5-8 hrs of photoperiod. Maximum flower production was noticed in rose under the conditions of 21-31 ^{0} C mean temperature, 60-80 per cent relative humidity and 6.5-8 hrs of photoperiod (Damake and Bhattacharjee, (1999). A decreased rate of flower abortion and an improvement of flower quality were observed in variety 'Frisco' when grown under low night temperature (Pien *et al.*,

2000). Monteiro *et al.* (2001) studied the flower respiration and longevity of five rose cultivars and reported that the cultivars 'Meijikatar' and 'Meirutral' had lowest respiration rates and greater flower longevity when grown during summer or spring as compared to fall or winter.

Shin *et al.* (2001) reported an increase in the leaf area, stem length, stem diameter and flower dry weight when temperature decreased from 30^{0} C – 15^{0} C.

Pampodakis *et al.* (2005) reported that roses grown during winter had shorter vase life than grown during summer and autumn whereas spring grown roses are having intermediate vase life. The effect of temperature integration on growth and development of roses were studied by Dielman *et al.* (2005) and remarked that the shoot length of cut flower roses get reduced by increasing temperatures by 0^{0} C, 6^{0} C and 10^{0} C from an average temperature of 20^{0} C and the reduction becomes stronger as integration period get increased. Wenjin *et al.* (2006) reported that the leaf area, fresh weight of leaf and plant, leaf number and plant height are correlated with cumulative daily mean solar radiation, cumulative day time and night time temperature respectively and they can be controlled by changing solar radiation and temperature. Ushio *et al.* (2008) reported that low temperature induced the functioning of several photosynthetic enzymes such as rubisco, stromal fructose-1, 6-bisphosphatase and sucrose-phosphate synthase.

A reduction in mean leaf area (26.7 %) and dry mass (32%) was recorded at high temperature (Pandey *et al.*, 2007). Younis *et al.* (2009) inferred that there was a highly significant interaction between temperature and number of flowers for cultivar 'Sahiwal' and maximum number of flowers were observed during the months of March, April and May which were significantly higher than other months.

The typical temperature recommendation for getting high shoot length and shoot weight in cultivar 'Kardinal' was at the time of bud emergence and in cultivar 'Milva' it is at leaf unfolding (Raviv *et al.*, 2010). A study to determine the stage of

development when flowers were most sensitive to high temperature stress was conducted by Greyvenstein *et al.* (2014) and reported that the cultivars 'Knock Out' and 'RAD razz' showed a 70 per cent reduction in flower weight under continuous stress conditions. Flowers were most sensitive to high temperature at visible bud stage.

Kajihara *et al.* (2015) reported that the dry matter accumulation and length of cut flower rose variety 'Applaudissements' were higher by 4 hr air conditioning at 18 ^{0} C or 21 ^{0} C

2.2.3. Relative Humidity

Mortensen and Fjeld (1998) studied the effect of air humidity, lightning period and lamp type on growth and vase life of cut rose variety 'Souvenir' and remarked that by increasing humidity the vase life of roses reduced from 8-13 to 2-5 days.

Mortensen *et al.* (2001) remarked that raising the humidity progressively increased plant height, specific leaf area, shoot: root ratio and vase life in pot rose Cv. 'Parade Fiesta'. Studies conducted by Torre and Fjeld (2001) in rose revealed that a moderate RH of 70 per cent resulted in a vase life of 15.5 days and at a higher RH of 90 per cent, the post-harvest life get reduced due to the malfunctioning of stomata.

Jin *et al.* (2013) reported dehumidification as an effective method for improving post-harvest longevity and quality of cut roses in green house production as the flowers under dehumidified environment exhibited an improvement in fresh weight, stem diameter as well as vase life compared to flowers grown under normal conditions.

2.2.3. Photo synthetically Active Radiation (PAR)

Carpenter *et al.* (1972) reported that the number of flowers per plant of four rose varieties was increased by extension of day length from 9-16 h with mixed wide

spectrum Gro-Lux and incandescent light of relatively low level of irradiance of 12 μmol s^{-1} m^{-2} PAR. Studies conducted by Mor and Halvey, (1980) revealed that red light reduced apical dominance, promoted sink activity, flower bud growth and development in rose. The quality of light is an important factor affecting bud sprouting in rose and the red light weakened apical dominance, promoted sink activity than blue light and promoted flower bud growth and development. Axillary and basal bud inhibition in roses due to lack of light was reported by Zieslin and Mor (1981).

Zieslin and Mor (1990) observed that the rose roots were damaged as a result of shading and light intensity affects the growth and flowering of rose plant. Menard and Danserea, (1995) observed higher numbers of flowers in cultivars 'After Glow'(41), 'Obsession' (36), and 'Royalty' (38) by lightning with high pressure sodium lamps as compared to metal halide lamp lighting. Mortensen and Fjeld (1998) studied the effect of air humidity, lightning period and lamp type on growth and vase life of cut rose variety 'Souvenir' and reported that longer and stronger shoots were produced by lightning using high pressure sodium lamps than that of fluorescent lamps at a photon flux density of 170 $\mu molm^{-2}s^{-1}$. A reduction in vase life was also observed when the lightning hours increased from 16 hours to 24 hours. High light intensity at lower night temperature increased the carbohydrate content of developing shoots and quality of flower stems in rose (Pien *et al.,* 2000).

Sarkka (2004) reported that when the outdoor global radiation is less than 600 μmol m^{-2} s^{-1} PPF , supplemental light of 100-200 μmol m^{-2} s^{-1} PPF along with HPS lamps installed very close to vegetation and pure carbon dioxide (800 ppm) can be recommended for the year round production of roses. Photosynthetic photon flux density of 220 μmol m^{-2} s^{-1} for 20 h per day increased yield in rose irrespective of season. One per cent increase in light intensity inside greenhouse increased the yield of rose from 0.5 to 1 per cent (Marcelis, 2006). According to Pettersen *et al.* (2006)

the numbers of flowers in roses were increased by 34 % on increasing lighting period from 18 to 24 hrs and also decreased the number of days to flower by 12 %. Dieleman and Meinen, (2007) reported an increased rate of leaf photosynthesis when radiation was doubled as 150-µmol m^{-2} s^{-1} at 20^0 C.

Kim and Lee (2008) observed an increased dry matter accumulation in cut rose cultivar 'Rote Rose' at high PAR and the effect of PAR on growth was dependent on night temperature. An increase in the level of applied fertilizer from 400:400:400 mg NPK per week per plant to 600:600:600 mg NPK per week per plant resulted in an increased biomass through increased light absorption by plants, soil reflected radiation and decreased soil reflected radiation (Desai, 2010)

Taro and Tomoyuki (2014) conducted an experiment to study the effect of long-day treatment using fluorescent lamps and supplemental lightning using LED`s on the yield of cut rose flowers and reported that photo synthetic photon flux density of 250µmol$m^{-2}s^{-1}$ increased the number, weight, stalk length and stem diameter of cut flowers over 60 cm long.

The growth and cut flower productivity of spray rose as affected by shading method during high temperature was investigated by Cheong*et al.* (2015) and the results revealed that 50 per cent aluminium shading treatment resulted in more marketable and exportable yield, increased flower stalk length, stem diameter, number of nodes, floret number, colour and longer vase life.

2.3. DIVERSITY ANALYSIS IN ROSE

The potential of existing rose germplasm collection was studied by Tejaswini and Dhananjaya (2006) and reported that the variability in stalk length and keeping quality indicates the possibility of utilising these varieties to develop better varieties through recombination. The varieties having stalk length of 42.36 cm or above and with keeping quality of 4.74 days or more and distinct colour groups were analysed for their

divergence. The cluster centre values and distance between the clusters can be utilised for hybridization in rose breeding programme

Cluster analysis of fourteen populations of rose species based on forty eight characters showed that there exists inter and intra specific variation among the rose species (Koobaz *et al.,* 2009). Zeinali *et al.* (2009) compared the yield and morphological characteristics of eleven *R. damascena* genotypes and classified the genotypes in to groups based on flower yield, flower number and average flower weight. The flower yield and flower number were correlated and flower yield and some of the morphological characters should be considered while selecting damask rose genotypes.

Kudori *et al.* 2015 reported that among fourty seven damask rose cultivars there was significant variation for most of the morphological traits. High variability was reported in characters *viz.* flower yield, number of flowers and flowering period. The flower yield per hectare positively and significantly correlated with number of flowers per plant, flowering period, plant height and canopy diameter. The flower dry weight and number of flowers per plant can be recommended as the selection criteria in damask rose breeding programmes.

Nasri *et al.* (2016) grouped 12 genotypes of damask roses into 4 clusters in terms of 12 traits using cluster analysis. Based on the grouping, the first cluster had maximum diversity with the third group in terms of the traits.

2.4. ESTIMATION OF GENETIC PARAMETERS IN ROSE

The study of the nature of association with various characters and the genetic variability available in rose genotypes plays a key role in the success of varietal evaluation. The magnitude of the genetic variability and different character association determines the success of any breeding programme as it enables a breeder to select most potent parents. Hence the genetic potentials of desirable characters and their relationship with each other need to be estimated for improving the knowledge about yield and yield contributing characters.

High GCV was reported for the characters like number of floral buds per plant, flower weight, number of petals per flower, number of branches per plant, plant height and plant spread while low GCV was observed for flower diameter in rose cultivars (Lal *et al.*, 1982).

The thorn density, plant height, plant spread and number of petals per flower showed high genotypic and phenotypic coefficient of variation coupled with high genetic advance and heritability and hence these characters were of greater importance in selection of hybrid tea roses (Palai *et al.*, 2003).

A continuous quantitative variation and heritability (68-92 per cent) in all the observed characters and selection based on total dry weight and leaf area are suggested by Yan *et al.* (2005).

Katiyar and Singh (2007) reported low GCV and PCV for plant height, number of branches per plant and test weight and high GCV and PCV for number of flowers per plant in *Rosa damascena.*

Twenty one hybrid tea rose varieties were evaluated by Verma *et al.* (2008 a) and reported high degree of genotypic and phenotypic coefficient of variation for thorn density followed by length of shoot after one month of bud sprouting, number of flowers per plant, length of sprouted bud, plant spread and length of shoot after 15 days of bud sprouting . Length of flower bud followed by number of flowers at first flush exhibited, highest degree of environmental coefficient of variation. The thorn density exhibited high degree of genotypic and phenotypic coefficient of variation, heritability, genetic advance and genetic advance as per cent mean.

Sewaniya, (2009) reported that the GCV, PCV, heritability and genetic advance as per cent of mean was higher in character number of thorns per 30 cm of stalk indicating the presence of additive gene action in expressing this character and selection for improvement of the character will be effective. The characters number of leaflets,

number of nodes and internodes per 30 cm of stalk, plant canopy, number of flowers per plant and number of leaflets per 30 cm of stalk were also exhibited similar trend.

Zeinali *et al.* (2009) reported that higher GCV and PCV for flower yield per plant, number of flowers per plant, number of petals per flower and lower GCV and PCV for length and width of flower bud was observed in *Rosa damascena*. The differences in GCV and PCV values were low in fresh weight of flower, length and width of flower bud indicating that they were less affected by environment.

Among thirty two genotypes of roses evaluated, all the vegetative and floral traits exhibited highly significant differences and higher GCV and PCV were observed for number of flowers per plant, flower weight, number of petals per flower, plant height, neck length and flower diameter. Number of flowers per plant exhibited high heritability, flower weight and number of petals exhibited high genetic advance in thirty two genotypes of rose (Panwar *et al.*, 2012).

The existence of wide variability and high heritability and genetic advance for various vegetative and floral characters among fifteen hybrid tea roses were reported by Janaki, (2013.)

Gitonga *et al.* (2014) compared the genetic variation, heritability and genotype by environment interaction of ten traits in a tetraploid rose population under four environments and reported that the traits number of petals and prickles on stems showed a low genotype-environment interaction and high heritability indicating that selection can be done in any of the four environments.

Gogoi *et al.* (2016) studied morphological characterization and extent of genetic variation in rose and reported high heritability coupled with high genetic advance in the character number of flowers per plant per year indicating that this character was governed by additive gene effect.

2.5. CORRELATION AND PATH COEFFICIENT ANALYSIS IN ROSE

Correlation and path coefficient analysis for flower yield in twenty genotypes of damask rose was done by Singh and Katiyar (2001) and reported that flower yield per

plant was positively and directly associated with number of flowers per plant and number of branches per plant. Medium plant height, prolific number of flowers per plant and flowering branches per plant should be considered while selecting damask roses for high flower yield.

Manjula, (2005) reported that the flower yield was significantly and positively correlated with height of the plant and quality attributes like shoot length, bud length, bud diameter, neck length, neck diameter and number of petals but negatively and significantly correlated with days to flower bud initiation and thorn density.

Tabaei-Aghdaei (2007) evaluated nine accessions of damask rose and reported that there were significant differences among these accessions in flower yield, flower number, single flower fresh and dry weight, flower dry matter percentage, petal and flower weight, number of petals, stamen and pistil. There was also a significant correlation with flower number and single flower weight.

Non significant positive correlation of number of flowers per plant was observed with days taken to bud sprouting, length of bud after 15 days of bud sprouting, number of flowers at first flush and total shelf life of flowers at phenotypic and genotypic level. The characters length of shoot after 15 days of bud sprouting, days taken for bud sprouting, diameter of flower bud, diameter of flower, thorn density and days taken for anthesis showed positive non significant correlation at environmental level (Verma *et al,*. 2008 b).

The correlation coefficients were found to be positive for leaf number, canopy diameter, flower number, plant height and flowering duration with flower weight and negatively correlated to petal number in genotypes of damask rose (Danyaei *et al.*, 2012). Panwar *et al*. (2012) investigated association of morphological characters through correlation and path coefficient analysis among thirty two rose cultivars and revealed that the number of flowers per plant was positively and significantly correlated with number of primary branches ((genotypic and phenotypic) and non significant and positive correlation for secondary branches (genotypic and phenotypic), bud length

(phenotypic) and internodal length (genotypic) levels. Significant and negative correlation (genotypic and phenotypic) was observed for neck length, flower diameter and flower weight with number of flowers per plant , length of bud after 15 days of bud sprouting.

Janaki, (2013) reported that genotypic correlation coefficients were higher than phenotypic correlation coefficient for most of the characters indicating lesser influence of environment in the expression of characters. Flower yield per plant registered a positive significant correlation with number of arms or productive shoots per plant, diameter of the stem at base, number of secondary shoots per plant, plant spread , biomass production per plant , dry matter production per plant , days required for flower development, tight bud length , diameter of flower at full opening stage, number of petals per flower, total number of flowers per plant, duration of flowering , stem length of cut flower , fresh weight of single cut flower, dry weight of single cut flower and per cent marketable cut flowers at phenotypic and genotypic levels. High positive direct effect on flower yield per plant on fresh weight basis was exerted by dry matter production per plant, total number of flowers per plant and fresh weight of single cut flower.

Materials and methods

3. MATERIALS AND METHODS

The research work entitled "Evaluation of rose varieties for commercial cultivation under the warm humid tropics of Kerala" was conducted in the Department of Floriculture and Landscaping during 2017-2018. The materials used and methodology adopted for the studies are presented in this chapter.

3.1. Geographical location of the site

Geographically the area is located at a latitude of 10^{0} 31 N and longitude of 76^{0} 13 E and lies 22-25 m above the Mean Sea Level.

3.2. Climate

The area experiences a tropical humid climate. The weather parameters recorded inside and outside the protected structure of experiment during the period of observation are presented in Appendix III.

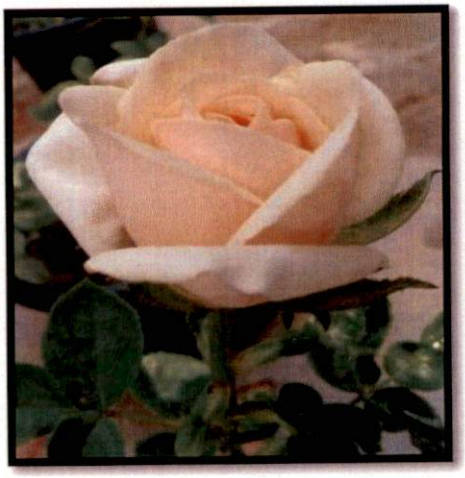
3.3 Experimental details

3.3.1. Varieties used for the experiment

Ten varieties each of cut flower and loose flower were selected for evaluation (Table 1. and plate 1 & 2).

Table 1. Varieties used for the experiment

SI.NO.	Cut flower varieties	Loose flower varieties
1.	Arka Ivory	Arka Parimala
2.	Arka Pride	Sherba Gold
3.	ArkaSwadesh	Mirabel



Arka Ivory

Arka Pride

Arka Swadesh

Plate 1.a. Cut flower varieties

Gold Strike

Noblesse

Revival

Plate 1 b. Cut flower varieties

Taj Mahal

Corvette

Emma

Plate 1 c. Cut flower varieties

Peach Avalanche

Plate 1 d. Cut flower varieties

Arka Parimala

Plate 2 a. Loose flower varieties

Sherba Gold

Mirabel

Vernish

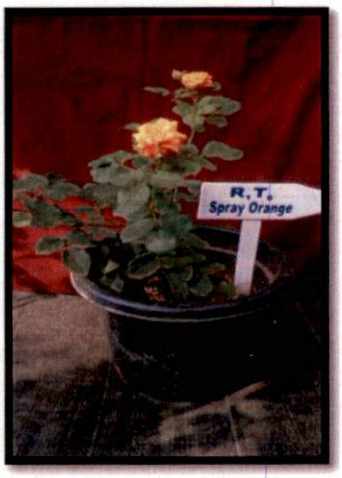
Plate 2 b. Loose flower varieties

Charisma

Jadiov

Star Light

Plate 2 c. Loose flower varieties



Spray Orange

Spray Yellow

Red Varnish

Plate 2d. Loose flower varieties

4.	Gold Strike	Vernish
5.	Noblesse	Charisma
6.	Revival	Jadiov
7.	Taj Mahal	Star Light
8.	Corvette	Spray Orange
9.	Emma	Spray Yellow
10.	Peach Avalanche	Red Varnish

3.3.2. Growing system

The selected rose varieties were evaluated under a naturally ventilated polyhouse of size 15 m X 12 m.

3.3.3. Planting and general management

Planting was done in pots of 20 x 25 cm size. Soil, Sand and FYM in 2:1:1 ratio was used as the medium. Six months old budded plants were used for planting. Uniform management practices were given for all varieties. Manuring was done as per IIHR recommendation for rose *i.e,* 160:120:240 kg NPK / acre. Pruning was done during October and need based application of plant protection chemicals were also done.

3.3.4. Design of the experiment

The experiment was laid out in CRD with ten treatments each of cut flower and loose flower varieties, three replications and five plants per treatment (Plate 3).

3.3.4.1. Treatments

3.3.4.1.1. Cut flowers

One month after planting

Peak flowering

Plate 3. General view of the field

T_1- Arka Ivory

T_2- Arka Pride

T_3 -Arka Swadesh

T_4- Gold Strike

T_5– Noblesse

T_6 - Revival

T_7 - Taj Mahal

T_8 - Corvette

T_9 - Emma

T_{10} - Peach Avalanche

3.3.4.1.2. Loose flowers

T_1- ArkaParimala

T_2- Sherba Gold

T_3- Mirabel

T_4- Vernish

T_5 - Charisma

T_6 - Jadiov

T_7 - Star Light

T_8 - Spray Orange

T_9 - Spray Yellow

T_{10} - Red Varnish

3.3.5. Observations

In each variety observations were recorded in six plants. The parameters recorded are as follows.

3.3.5.1. Quantitative characters

3.3.5.1.1. Vegetative characters

Observations on vegetative characters were recorded at biweekly intervals

3.3.5.1.1.1. Plant height

The height of the plant was recorded by measuring from base to the tip of the main shoot and expressed in cm.

3.3.5.1.1.2. Plant spread (EW and NS)

The growth of the plant in both direction *i.e.*, North South and East West were recorded and the average was expressed in cm.

3.3.5.1.1.3. Number of sprouts

The number of primary shoots produced from the budded portion of the plant were counted and recorded.

3.3.5.1.1..4. Number of branches /plant

Total number of branches produced from the primary shoots of the plant were counted and recorded.

3.3.5.1.1.5. Number of leaves /branch

Total number of leaflets produced on each branch at the time of observation were counted and recorded.

3.3.5.1.2. Floral characters

3.3.5.1.2.1. Cut flowers and loose flowers

3.3.5.1.2.1.1. Days taken for emergence to opening of flower buds

Number of days taken from emergence of visible bud to the unfurling of one or two rows of outer petals was recorded (Plate 4 a).

3.3.5.1.2.1.2. Length of flower bud

The length from the base of the flower bud to the tip was measured and expressed in cm.

3.3.5.1.2.1.3. Diameter of flower bud

The maximum diameter of the flower bud was measured and expressed in cm.

3.3.5.1.2.1.4. Number of flowers/sprout

Total number of flowers produced in each sprout were counted and recorded.

3.3.5.1.2.1.5. Number of flowers / plant

Total number of flowers produced in a plant were counted and recorded

3.3.5.1.2.1.6. Number of petals / flower

Total number of petals in a flower at fully opened stage were counted and recorded.

3.3.5.1.2.1.7. Flower diameter at fully opened stage

Diameter of the flower was taken at its fully opened stage and expressed in cm.

3.3.5.1.2.1.8. Flower persistence

Number of days from commercial stage of harvest to wilting of petals of outer row were counted and recorded.

3.3.5.1.2.1.9. Duration of flowering

Number of days from emergence of first visible bud to the emergence of last flower bud, during the period of observation were counted and recorded.

3.3.5.1.2.1.10. Yield of marketable flowers

The average number of marketable flowers produced per plant was recorded as yield of marketable flowers in case of cut flowers. Average number of marketable flowers produced per plant was multiplied with the average fresh weight of a single flower and expressed in gram in case of loose flowers.

3.3.5.1.2.2. Cut flowers

3.3.5.1.2.2.1. Length of flower shoot

Length from the base of the shoot to terminal node was taken and expressed in cm (Plate 4).

(a) (b) (c)

a) Flower at visible bud emergence stage, b) commercial stage of harvest of cut flower, c) commercial stage of harvest of loose flower

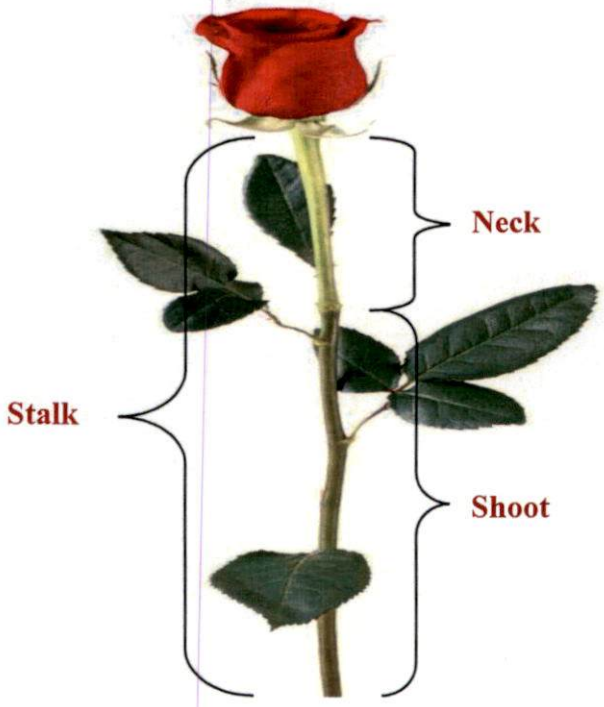


Plate 4. Parts of cut flower

3.3.5.1.2.2.2. Thickness of flower shoot

Diameter of the flower shoot was taken and expressed in cm.

3.5.1.2.2.3. Neck length

Length was measured from the end of first terminal node to the base of the flower and expressed in cm.

3.3.5.1.2.2.4. Neck girth

Perimeter of the neck was taken and expressed in cm.

3.3.5.1.2.2.5. Stalk length of the flower

The length from the base of the shoot to base of flower was taken and expressed in cm.

3.3.5.1.2.2.6. Stalk girth of the flower

Perimeter of the stalk was taken and expressed in cm.

3.3.5.2. Qualitative characters

Observations on qualitative vegetative as well as floral parameters were taken as per DUS guidelines and as per the methods given by Nadeem *et al.* (2011) and Hosur *et al.* (2015).

3.3.5.2.1. Vegetative characters

3.3.5.2.1.1. Bush shape

Bush shape was determined based on the plant growth habit. The rating given was upright-1, semi upright- 3, intermediate- 5, moderately spreading-7 and strongly spreading-9 (DUS guidelines) (Plate 5).

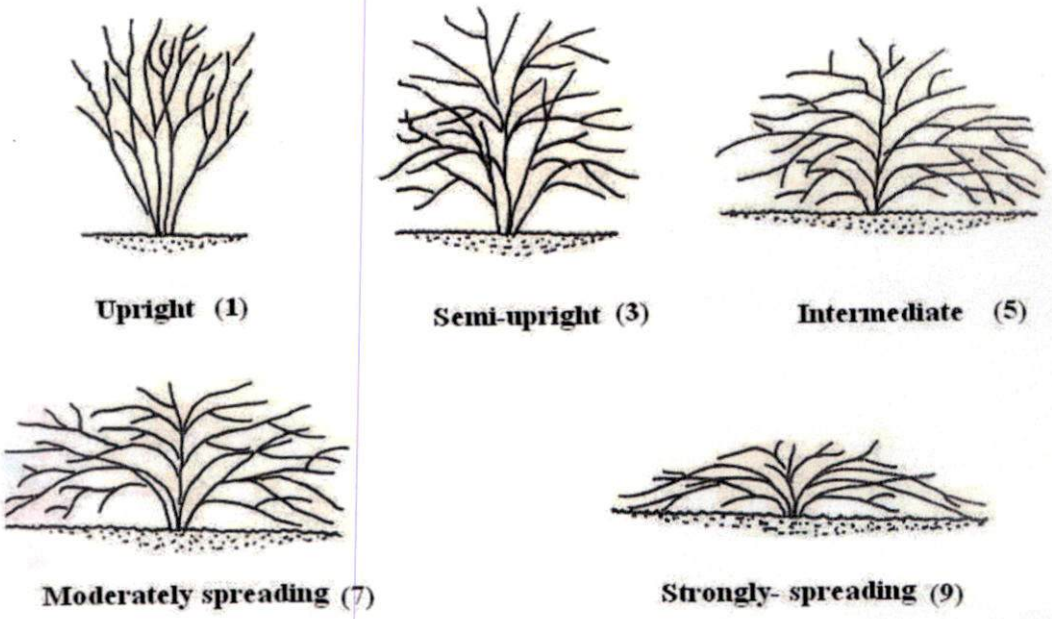


Plate 5. Bush shape of rose varieties

Plate 6. Inflorescence type of rose varieties

3.3.5.2.1.2. Amount of prickles

Amount of prickles present on the stem was assessed based on a rating scale as absent -1, few-3, medium-5 and many-7 (DUS guidelines).

3.3.5.2.1.3. Leaf colour

Leaf colour was rated based on the intensity of green colour as very light-1, light-3, medium-5, dark -7 and very dark- 9 (DUS guidelines).

3.3.5.2.1.4. Leaf margin

Leaf margins were classified based on serration on leaf margin as absent-1, fine-3, medium-5 and dense-7 (DUS guidelines).

3.3.5.2.1.5. Leaf hairiness

Leaf hairiness was recorded by visual observations. If it is present, was regarded as positive (+), if absent then negative (-), (Nadeem *et al*. 2011).

3.3.5.2.2. Floral characters.

3.3.5.2.2.1. Flower colour

Flower colour was recorded as per Royal Horticultural Society Colour Charts (RHSCC - 2015). The rating of colour was given according to the DUS guidelines as white blend-1, yellow blend-2, orange blend-3, pink blend-4, and red blend-5 (DUS guidelines).

3.3.5.2.2.2. Inflorescence type

On the basis of inflorescence type flowers were classified as solitary or clustered (Nadeem *et al*., 2011) (Plate 6).

3.3.5.2.2.3. Number of thorns per 10 cm of stalk length

It was recorded by counting number of thorns present per 10 cm of flower shoot and rated as absent -1, few-3, medium-5, many-7 (DUS guidelines).

3.3.5.2.2.4. Fragrance

Fragrance was evaluated with rating scale as, highly fragrant-1, medium fragrant-2, less fragrant-3, no fragrance-4 (DUS guidelines).

3.3.5.2.2.5. Absence of blemishes and overall appearance

This parameter was recorded by visual observation and rated as excellent -5, good- 4, fair -3 , average -2 , poor -1 (Hosur *et al*., 2015).

3.3.5.2.2.6. Incidence of pest and diseases

Varieties were observed for incidence of pest and disease and recorded.

3.3.5.3. Post harvest studies

3.3.5.3.1. Cut flowers

3.3.5.3.1.1. Fresh weight of the flower

Weight of the flower along with the stalk was taken and expressed in g.

3.3.5.3.1.2. Physiological loss in weight (g)

Difference between fresh weight of the flower and weight of the flower at the end of vase life was taken and expressed in g.

3.3.5.3.1.3. Total water uptake (ml)

Total water uptake was measured as the difference between initial volume of water in the vase and volume at the end of vase life and expressed in ml.

3.3.5.3.1.4. Vase life

Flowers were harvested at commercial stage of harvest *i.e.*, when calyx reflexed and the outer petals unfurled and kept in tap water. The number of days taken for wilting of outer row of petals were counted and recorded as vase life.

3.3.5.3.2. Loose flowers

3.3.5.3.2.1. Fresh weight of the flower

Weight of the fully opened flowers were taken and expressed in gram.

3.3.5.3.2.2. Number of petals per flower

Number of petals in a flower was counted at its fully opened stage and recorded.

3.5.2.2.3. Weight of petals per flower

Weight of the petals per flower was taken and expressed in gram.

3.5.2.2.4. Shelf life

Flowers were harvested at fully opened stage and kept under room temperature. The number of days taken for starting of wilting was counted and recorded.

3.3.5.4. Overall performance of rose varieties

Overall performances of varieties were assessed based on following score cards.

Table 2. Score card for overall performance of cut flower varieties

Stalk length (cm)	Number of petals	Length of flower bud (cm)	Diameter of flower bud (cm)	Vase life (days)	Number of marketable flowers
• > 30 - 1 • 20-30- 2	• 40-1 • 30-40-2 • 20-30-3 • 10-20-4	• 2-3 -1 • 1-2 - 2 • <1 -3	• 1-2- 1	• 4-5- 1 • 3-4-2 • 2-3-3 • 1-2-4	• 5-10- 1 • 1-5 - 2

Table 3. Score card for overall performance of loose flower varieties

Number of petals	Fragrance	Flower diameter (cm)	Number of marketable flowers
• > 70 - 1 • 60-70-2 • 50-60-3 • 40-50-4 • 30-40-5 • 20-30-6 • 10-20-7	• Strong -1 • Medium -2 • Weak -3 • Absent -4	• 6-7 -1 • 4-5 -2 • 2-3 -3	• 30-40 -1 • 20-30 -2 • 10-20 -3

3.3.5.4. Meteorological parameters

Observations on meteorological parameters like temperature and relative humidity were taken daily thrice *viz.* 8.15 am, 12 pm and 3 pm using Thermo hygrometer. Temperature was expressed in ^{0}C and Relative Humidity as per cent and Photosynthetically Active Radiation was measured at monthly intervals using Digital plant canopy analyser and expressed in $\mu molm^{-2}s^{-1}$.

3.5.4. Statistical analysis

3.5.4.1 Analysis of variance (ANOVA)

The data for different characters were statistically analysed for completely randomised block design. The skeleton of ANOVA is as follows.

ANOVA

Source of variation	Degrees of freedom (df)	Total Sum of squares (TSS)	Mean sum of squares (MSS)	F ratio
Treatments	V-1	$\frac{£T\,i^2}{r_i}$ - C.F	$\frac{T_rMS}{V-1}$	$\frac{T_rMSS}{EMSS}$
Error	n-v	ESS	$\frac{ESS}{n-v}$	
Total	n-1	$£Y^2_{ij}$- C.F		

Where,

V = Number of genotypes or treatments

MSS = Mean sum of squares

ESS = Error sum of squares

T_rMSS = Mean sum of squares due to treatments

EMSS = Mean sum of squares due to error

Data pertaining to various vegetative, floral and post harvest aspects were statistically analysed using WASP statistical software.

3.6. Diversity analysis

Diversity plays a key role in the continuity of a species as it helps to survive with the changes in the environment by providing adaptation to existing biotic and abiotic environmental conditions.

3.6.1. D^2 Statistics

The genetic association among genotypes based on qualitative and quantitative characters of rose varieties was measured by Euclidean distance using NTSYSpc software. Clustering analysis was carried out based on Jaccard`s similarity matrix and constructed a dendrogram by agglomerative method (Day and Edelsbrunner, 1984).

3.7. Estimation of genetic parameters

The genetic parameters like genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability in broad sense and genetic gain and genetic advance as percent of mean (GAM) for different floral traits were estimated for all cut flower and loose flower varieties under study using the following standard procedures.

3.7.1. Phenotypic and genotypic coefficients of variation (PCV and GCV)

Genotypic coefficients of variation were calculated according to the formula, given by Burton (1952),

$$GCV = \frac{\sigma_g}{\text{Grand mean}} \times 100$$

Where, σ_g is genotypic standard deviation

$$PCV = \frac{\sigma_p}{\text{Grand mean}} \times 100$$

Where σ_p is phenotypic standard deviation

The PCV and GCV value were categorised as described by Sivasubramanian and Menon (1973).

- 0 to 10% - low
- 10.1 to 20% - moderate
- > 20% - high

3.5.2. Heritability in broad sense (H^2)

$$\text{Heritability } (\mathbf{H^2}) = \frac{Vg}{Vp} \times 100$$

Where V_g is genotypic variance and V_p is phenotypic variance

Range of heritability was classified by Robinson *et al.* (1949)

- 0 to 30% - low
- 31 to 60% - moderate

- 61% and above - high

3.5.3. Genetic advance (GA)

The genetic advance was calculated according to Johnson *et al.* (1955)

$GA = K \times \sigma_p \times H^2$

Where, K= 2.06, a constant

σ_p = Phenotypic standard deviation

3.5.4. Genetic advance as percent of mean (GAM)

$$GAM = \frac{GA}{\text{Grand mean}} \times 100$$

The range of genetic advance as percent of mean was categorised into

- Low- less than 10%
- Moderate – 10-20 %
- High - More than 20 %

3.6. Correlation studies

Genotypic and phenotypic correlation coefficients were calculated as suggested by Al- Jibourie*et al.* (1958).

Genotypic correlation $= r_{xy}(g) = Cov_{xy}(G)/ [V_x(G) \times V_y(G)]^{1/2}$

Phenotypic correlation $= r_{xy}(p) = Cov_{xy}(P)/ [V_x(P) \times V_y(P)]^{1/2}$

Where,

$Cov_{xy}(G)$ - Genotypic covariance between x and y

$Cov_{xy}(P)$ - Phenotypic covariance between x and y

$V_x(G)$ - Genotypic variance of character 'x'

$V_x(P)$ - Phenotypic variance of character 'x'

$V_y(G)$ - Genotypic variance of character 'y'

$V_y(P)$ - Phenotypic variance of character 'y'

The test of significance for association between characters was done by comparing table r values at n-2 degrees of freedom with estimated values.

3.7. Path coefficient analysis

Path coefficient analysis suggested by Wright (1921) and elaborated by Dewey and Lu (1959) were carried out to find direct and indirect effect of the morphological characters on bunch yield. The following equations were used for finding direct and indirect effects.

$$r_{1y} = a + r_{12}b + r_{13}c + \ldots\ldots\ldots\ldots\ldots + r_{1Ii}$$

$$r_{2y} = a + r_{21}a + b + r_{23}c + \ldots\ldots\ldots\ldots\ldots + r_{2Ii}$$

$$r_{Iy} = r_{I1}a + r_{I2}b + r_{I3}c + \ldots\ldots\ldots\ldots\ldots + I$$

Where,

r_{1y} to r_{Iy} = Coefficient of correlation between casual factors 1 to I with dependent variable y.

r_1 to r_I = Coefficient of correlation among casual factors

a, b,c…I = Direct effect of characters 'a' to 'I' on y.

Residual effect (R) = $1- \sqrt{a^2 + b^{2+} c^2 + \ldots\ldots\ldots i^2 + 2abr_{12} + 2acr_{13} + \ldots.}$

Scale for path analysis

A scale suggested by Lenka and Mishra (1973) for the importance of direct and indirect effect values is as follows:

Rate of scale	**Values of direct and indirect effects**
Negligible	0.00- 0.09
Low	0.10 - 0.19
Moderate	0.20- 0.29
High	0.30- 0.99
Very high	More than 0.99

Results

4. RESULTS

The investigation entitled Evaluation of rose varieties for commercial cultivation under the warm humid tropics of Kerala was conducted in the Department of Floriculture and landscaping, College of Horticulture, Vellanikkara during the months of August 2017 to March 2018. Ten cut flower and ten loose flower rose varieties were selected for evaluation. Observations on various vegetative characters and floral parameters were taken. The results of the experiment are as follows.

4.1. ANALYSIS OF VARIANCE

4.1.1. Cut flowers

Analysis of variance for different vegetative and floral characters is represented in Table 4. All the characters except duration of flowering, flower persistence, flower diameter at fully opened stage, shoot length, shoot thickness, stalk girth and neck girth was significantly different among the cut flower varieties.

4.1.2. Loose flowers

Analysis of variance for different vegetative and floral characters is represented in Table 5. All the characters except plant spread and shelf life was significantly different among the loose flower varieties.

4.2. VEGETATIVE CHARACTERS

The observations on vegetative characters taken at biweekly intervals and for the comparison of varieties, the data during the period of flower bud emergence and at peak flowering were considered.

4.2.1. Cut flower

Table 4. Analysis of variance of cut flower varieties

Sl. No.	Character		Mean sum of squares	
			Treatment	Error
1	Plant height	Flower emergence	103.595*	3.227
		Peak flowering	55.45	4.56
2	Plant spread	Flower emergence	36.557*	8.492
		Peak flowering	80.901*	3.536
3	Number of sprouts	Flower emergence	32.12*	22.34
		Peak flowering	85.2*	33.2
4	Number of branches	Flower emergence	3.170*	0.217
		Peak flowering	2.996*	0.263
5	Number of leaves	Flower emergence	131.189*	4.783
		Peak flowering	202.685*	2.425
6	Days taken for emergence to opening of flower buds		3.533*	0.598
7	Flower persistence (Days)		4.472	2.065
8	Duration of flowering (Days)		444.578	396.033
9	Length of flower bud (cm)		0.151*	0.050
10	Diameter of flower bud (cm)		0.058*	0.009
11	Number of petals per flower (cm)		988.738*	29.042
12	Flower diameter at fully opened stage (cm)		0.507	0.307
13	Length of the flower shoot (cm)		27.325	9.611
14	Thickness of flower shoot (cm)		0.130	0.076
15	Length of neck (cm)		2.466*	0.203
16	Girth of neck (cm)		0.038	0.019
17	Length of flower stalk (cm)		21.050*	10.656
18	Girth of the flower stalk (cm)		0.130	0.076
19	Number of flowers per sprout		30.290*	0.550
20	Number of flowers per plant		20.247*	2.461
21	Number of marketable flowers		10.107*	0.552
22	Fresh weight of the flower (g)		8.847*	0.342
23	Physiological loss in weight (g)		0.782*	0.173

*Significant at 5% level

Table 5. Analysis of variance of loose flower varieties

Sl. No.	Character		Mean sum of squares	
			Treatment	Error
1	Plant height	Flower emergence	8.445*	1.140
		Peak flowering	246.797*	8.966
2	Plant spread	Flower emergence	11.477	9.542
		Peak flowering	24.880	13.845
3	Number of sprouts	Flower emergence	1.079*	0.133
		Peak flowering	1.848*	0.117
4	Number of branches	Flower emergence	3.115*	0.242
		Peak flowering	2.685*	0.369
5	Number of leaves	Flower emergence	274.676*	9.268
		Peak flowering	110.028*	21.702
6	Days taken for emergence to opening of flower buds		3.847*	1.074
7	Flower persistence (Days)		11.894*	2.568
8	Duration of flowering (Days		352.830*	133.267
9	Length of flower bud (cm)		0.246*	0.016
10	Diameter of flower bud (cm)		0.046*	
11	Number of petals per flower (cm)		1789.645*	3.425
12	Flower diameter at fully opened stage (cm)		3.516*	0.250
13	Number of flowers per sprout		0.448*	0.106
14	Number of flowers per plant		103.117*	2.612
15	Yield of marketable flowers		171.052*	9.632
16	Fresh weight of the flower (g)		1.533*	0.032
17	Weight of petals per flower		1.286*	0.069

*Significant at 5% level

The vegetative characters of cut flower varieties at biweekly intervals are furnished in Appendix I and at the period of flower bud emergence and peak flowering stages are represented in Table 6.

4.2.1.1. Plant height

No significant variation in plant height of cut flower varieties could be observed up to January. From February onwards the varieties Arka Pride, Taj Mahal and Emma were superior in terms of this parameter and lowest plant height was observed in variety Gold Strike. (Appendix I.1).

Plant height at flower emergence period was highest in variety Taj Mahal (42.17 cm) whereas at peak flowering stage, even though not significant, highest plant height was in Taj Mahal (52.83 cm) and lowest in Peach Avalanche (33.08 cm) (Table 6).

4.2.1.2. Plant spread

Plant spread varied significantly among the varieties except at initial month and during January- February (Appendix I.2). Highest plant spread at flower bud emergence was observed in Arka Ivory (23.67 cm), Gold Strike (27.58 cm), Revival (25.33 cm), Taj Mahal (24.83 cm) and Peach Avalanche (23.50 cm) whereas at peak flowering stage, varieties Revival (39.13 cm) and Arka Swadesh (36.25 cm) had the highest plant spread (Table 6).

4.2.1.3. Number of sprouts

There was significant variation in the number of sprouts among the varieties during the period of observation (Appendix I.3). Highest number of sprouts at flower bud emergence was observed in varieties Arka Ivory (2.17) and Gold Strike (2) whereas at peak flowering, highest number of sprouts was produced by the varieties Gold Strike

Table 6. Vegetative characters of cut flower varieties at flower emergence stage and peak flowering stage

Variety	Plant height (cm)		Plant spread (cm)		Number of sprouts		Number of branches		Number of leaves	
	Flower emergence	Peak flowering	Flower emergence	Peak flowering	Flower emergence	Peak flowering	Flower emergence	Peak flowering	Flower emergence	Peak flowering
T_1(Arka Ivory)	28.67	41.92	23.67	30.50	2.17	2.00	3.33	4.00	32.50	38.67
T_2(Arka Pride)	27.50	44.83	22.42	24.50	1.33	1.67	4.67	3.25	24.83	20.50
T_3 (Arka Swadesh)	31.00	44.00	22.42	36.25	1.17	1.67	4.00	3.50	21.83	43.33
T_4(Gold Strike)	33.08	41.17	27.58	28.17	2.00	2.83	4.50	3.67	33.50	26.50
T_5(Noblesse)	37.33	43.32	19.83	23.13	1.00	1.67	3.67	2.33	25.33	34.33
T_6(Revival)	25.33	43.00	25.33	39.13	1.00	1.33	4.50	5.50	27.00	26.50
T_7(Taj Mahal)	42.17	52.83	24.83	29.69	1.17	1.50	3.50	3.50	31.83	35.33
T_8(Corvette)	24.83	38.33	16.00	24.50	1.00	1.00	2.50	2.58	11.17	17.67
T_9(Emma)	25.33	37.83	18.17	26.88	1.00	1.17	3.67	4.50	21.17	21.33
T_{10}(Peach Avalanche)	25.50	33.08	23.50	26.83	1.50	2.17	6.33	5.00	25.17	27.50
CD (5%)	**3.06**	**NS**	**4.97**	**6.49**	**0.41**	**0.68**	**0.79**	**0.87**	**3.73**	**2.65**
CV	**5.97**	**16.57**	**13.02**	**3.20**	**18.11**	**14.58**	**11.45**	**13.54**	**8.60**	**5.53**

(2.83) and Peach Avalanche (2.17). Lowest number of sprouts were observed in variety Corvette (1) (Table 6).

4.2.1.4. Number of branches

There was significant variation in number of branches during first month of planting and all the varieties except Corvette were performing on par with highest number of branches during this month (Appendix I.4). Highest number of branches at flower bud emergence and at peak flowering (6.33) was observed in variety Peach Avalanche (6.55) whereas lowest number of branches at peak flowering stage was observed in variety Noblesse (2.33) (Table 6).

4.2.1.5. Number of leaves per branch

No significant variation in number of leaves of cut flower varieties could be observed during the period of observation except in the months of November, January, March, and May (Appendix I.5). Arka Ivory, Gold Strike and Taj Mahal had highest number of leaves at flower bud emergence stage. Highest number of leaves was observed in variety Arka Ivory (43.33) whereas lowest was reported in variety Corvette (17.67) at peak flowering stage (Table 6).

4.2.1.6. Qualitative characters

Data pertaining qualitative vegetative characters are furnished in Table 7.

.4.2.1.6.1. Bush shape

Upright growth habit was exhibited by variety Corvette (1) with less number of branches whereas varieties Arka Ivory, Arka Pride, Noblesse and Taj Mahal exhibited semi upright growth habit (3) with medium number of branches. Moderately spreading branches (7) were present in varieties Arka Swadesh, Peach Avalanche and Gold Strike whereas variety Emma exhibited Intermediate growth habit and strongly spreading branches were present in variety Revival (9).

Table 7. Qualitative characters of cut flower varieties (Vegetative)

Variety	Bush shape	Amount of prickles	Leaf colour	Leaf margin	Leaf hairiness
T_1(Arka Ivory)	Semi upright	Many	Dark	Fine	Absent
T_2(Arka Pride)	Semi upright	Many	Very dark	Dense	Absent
T_3 (Arka Swadesh)	Moderately spreading	Many	Very dark	Medium	Absent
T_4(Gold Strike)	Moderately spreading	Medium	Very dark	Dense	Absent
T_5(Noblesse)	Semi upright	Many	Medium	Medium	Absent
T_6(Revival)	Strongly spreading	Medium	Medium	Dense	Absent
T_7(Taj Mahal)	Semi upright	Medium	Dark	Medium	Absent
T_8(Corvette)	Upright	Medium	Light	Dense	Absent
T_9(Emma)	Intermediate	Absent	Light	Medium	Absent
T_{10}(Peach Avalanche)	Moderately spreading	Few	Dark	Medium	Absent

Rating scale

- **Bush shape**: Upright-1, Semi upright- 3, Intermediate- 5, moderately spreading-7, Strongly spreading-9
- **Amount of prickles**: Absent -1, Few-3, Medium-5, Many-7
- **Leaf colour**: Very light-1, Light -3, Medium-5, Dark -7, Very dark- 9
- **Leaf margin**: Absent-1, Fine-3, Medium-5, Dense -7
- **Leaf hairiness**: If present (+) and if absent negative (-)

4.2.1.6.2. Amount of prickles

High amount of prickles (7) were seen on the varieties Arka Ivory, Arka Pride, Arka Swadesh, Gold Strike and Noblesse with more than twenty prickles per 10 cm of vegetative shoot. Revival, Taj Mahal and Corvette recorded medium number of prickles (5) ranging from 10-20. Peach Avalanche had very few prickles (3) varied from 1-10 while the variety Emma was relatively prickle less (1).

4.2.1.6.3. Leaf colour

Among cut flower varieties light green coloured leaves were observed in Corvette and Emma (3). Varieties Noblesse and Revival had medium green coloured leaves (5). Dark green (7) coloured leaves were observed in Arka Ivory, Taj Mahal and Peach Avalanche and very dark green (9) coloured leaves were found in Arka Pride, Arka Swadesh, and Gold Strike.

4.2.1.6.4. Leaf margin

Varying degrees of serrations were observed in all varieties of cut flower and loose flowers as the number and angle of serrations are characteristic of each variety. Leaves with fine serration (3) were observed in variety Arka Ivory. Arka Swadesh, Noblesse, Taj Mahal, Peach Avalanche and Emma were found to have medium serration (5) while the varieties Arka Pride, Gold Strike, Revival and Corvette recorded dense serration (7) in leaf margin.

4.2.1.6.5. Leaf hairiness

All the cut flower varieties were having leaves without hairs and the petioles in all the leaves were having spines on lower parts in varying degrees.

4.2.1..2. Loose flowers

The data pertaining to various quantitative vegetative characters are represented in Appendix II and at flower bud emergence and peak flowering is given in Table 8.

4.2.1.2.1. Plant height

Regarding plant height of loose flower varieties, there was no significant variation up to December. From January to March, varieties Arka Parimala, Vernish, Jadiov and Star Light were superior in terms of plant height (Appendix II. 1).

Plant heights at flower bud emergence and at peak flowering were superior in variety Arka Parimala (59.82 cm) whereas lowest plant height was reported in varieties Mirabel (28.08 cm) and Red Varnish (32.83 cm) (Table 8).

4.2.1.2.2. Plant spread (cm)

The plant spread of the varieties not differed significantly at flower bud emergence and at peak flowering. However superiority of the variety Arka Parimala was observed during both the time periods (Appendix II. 2 and Table 8).

4.2.1.2.3. Number of sprouts

Number of sprouts in loose flower varieties varied significantly over the months. The varieties Star Light and Charisma were having highest number of sprouts at flower bud emergence period whereas at peak flowering, highest number of sprouts was observed in variety Charisma (4) followed by Star Light (2.83) (Appendix II.3 and Table 8).

4.2.1.2.4. Number of branches

Regarding number of branches of loose flowers, there was no significant variation except in December and April months. The varieties Mirabel and Star Light had highest number of branches at flower bud emergence whereas at peak flowering,

Table 8. Vegetative characters of loose flower varieties at flower emergence stage and peak flowering stage

Variety	Plant height (cm)		Plant spread (cm)		Number of sprouts		Number of branches		Number of leaves	
	Flower emergence	Peak flowering	Flower emergence	Peak flowering	Flower emergence	Peak flowering	Flower emergence	Peak flowering	Flower emergence	Peak flowering
T_1 (Arka Parimala)	22.50	59.82	26.75	33.17	1.33	1.67	4.50	6.67	29.33	26.00
T_2 (Sherba Gold)	16.00	42.78	23.92	33.50	1.17	1.67	3.50	4.17	36.15	36.13
T_3 (Mirabel)	19.08	28.08	24.08	27.42	1.00	1.50	6.00	4.63	34.33	25.17
T_4 (Vernish)	18.67	47.05	27.75	34.42	1.17	2.17	4.83	4.83	52.33	41.17
T_5 (Charisma)	18.17	42.08	26.25	29.08	2.17	4.00	4.17	5.50	31.17	34.00
T_6 (Jadiov)	17.83	42.83	23.67	28.33	1.83	1.83	3.83	6.50	45.00	34.67
T_7 (Star Light)	19.33	52.72	27.58	31.83	2.50	2.83	5.83	5.50	50.83	44.47
T_8 (Spray Orange)	18.33	39.25	24.79	28.83	1.00	1.58	3.50	3.67	28.67	33.83
T_9 (SprayYellow)	17.58	40.50	22.42	30.33	1.00	1.58	5.17	5.50	24.67	31.10
T_{10}(Red varnish)	19.50	32.83	22.75	25.71	1.83	2.33	3.00	5.50	40.50	37.97
CD (5 %)	**1.82**	**5.10**	**NS**	**NS**	**0.38**	**0.82**	**0.84**	**1.03**	**5.19**	**7.94**
CV	**5.71**	**7**	**12.36**	**12.30**	**14.91**	**16.14**	**11.09**	**11.57**	**8.16**	**13.52**

highest number of branches was observed in variety ArkaParimala (6.67) and Jadiov (6.5) (Appendix II.4 and Table 8).

4.2.1.2.5. Number of leaves per branch

Regarding loose flower varieties significantly different numbers of leaves were observed among the varieties and the highest number of leaves at flower bud emergence and at peak flowering was in varieties Star Light (50.83, 44.47) and Vernish (52.33, 41.17) (Appendix II.5 and Table 8)

4.2.1.2.7. Qualitative characters

The qualitative characters of vegetative observations are given in Table 9.

4.2.1.2.6.1. Bush shape

Among loose flower varieties upright growth habit (1) was reported in variety Sherba Gold whereas variety Spray Orange exhibited semi up right (3) growth habit. The varieties Arka Parimala, Mirabel and Charisma exhibited moderately spreading growth habit (5) while strongly spreading growth habit (7) was exhibited by Vernish. Intermediate growth habit was present in varieties Jadiov, Star Light, Spray Yellow, and Red Varnish.

4.2.1.2.6.2. Amount of prickles

Among loose flower varieties high amount of prickles (7) were found in Arka Parimala and Mirabel while the varieties Sherba Gold, Vernish, Charisma, Jadiov, Star Light and Red varnish were having medium number of prickles (5). Spray Orange and Spray Yellow had very few prickles (3).

4.2.1.2.6.3. Leaf colour

Table 9. Qualitative characters of loose flower varieties (Vegetative)

Variety	Bush shape	Amount of prickles	Leaf colour	Leaf margin	Leaf hairiness
T_1 (Arka Parimala)	Moderately spreading	Many	Dark	Light	Absent
T_2 (Sherba Gold)	Upright	Medium	Very dark	Light	Absent
T_3 (Mirabel)	Moderately spreading	Many	Very dark	Dense	Absent
T_4 (Vernish)	Strongly spreading	Medium	Light	Light	Absent
T_5 (Charisma)	Moderately spreading	Medium	Medium	Dense	Absent
T_6 (Jadiov)	Intermediate	Medium	Medium	Medium	Absent
T_7 (Star Light)	Intermediate	Medium	Dark	Dense	Absent
T_8 (Spray Orange)	Semi upright	Few	Dark	Dense	Absent
T_9 (SprayYellow)	Intermediate	Few	Dark	Dense	Absent
T_{10}(Red varnish)	Intermediate	Medium	Very dark	Dense	Absent

Rating scale

- **Bush shape**: Upright-1, Semi upright- 3, Intermediate- 5, moderately spreading-7, Strongly spreading-9
- **Amount of prickles**: Absent -1, Few-3, Medium-5, Many-7
- **Leaf colour**: Very light-1, Light -3, Medium-5, Dark -7, Very dark- 9
- **Leaf margin**: Absent-1, Fine-3, Medium-5, Dense -7
- **Leaf hairiness**: If present (+) and if absent negative (-)

Loose flower varieties exhibited green colour in varying degrees. Light green (3) coloured leaves were observed in Vernish while medium green (5) coloured leaves were observed in Jadiov and Charisma. Varieties Arka Parimala, Star Light, Spray Orange Orange and Spray Yellow were having dark green leaves (7) whereas very dark green leaves were observed in Sherba Gold, Mirabel and Red Varnish.

4.2.1.2.6.4. Leaf margin

Loose flower varieties also exhibited serrations in varying degrees. Fine serration (3) was observed in Arka Parimala, Sherba Gold and Vernish. Medium serration (5) was found in Jadiov while the varieties Mirabel, Charisma, Star Light, Peach Avalanche, Spray Orange and Spray Yellow had dense serration in leaf margin (7).

4.2.1.2.6.5. Leaf hairiness

All the loose flower varieties were having leaves without hairs and the petioles were having spines on lower parts in varying degrees in all varieties.

4.3. FLORAL CHARACTERS

4.3.1. Cut flower

4.3.1.1 Flowering characteristics

Data pertaining to the flowering characteristics are furnished in Table 10.

4.3.1.1.1. Days taken from emergence to opening of flower buds

Significant variation was observed among varieties in number of days taken for initiation to opening of flower buds and the varieties Emma, Arka Ivory and Gold Strike recorded minimum number of days (11.73, 13.01 and 13.84 respectively) for initiation to opening of flower buds and the variety Peach Avalanche took highest number of days (15.11) from initiation to opening of flower buds.

Table 10. Flowering characteristics of cut flower varieties

Variety	Days taken for emergence to opening of flower buds	Flower persistence (Days)	Duration of flowering (Days)
T_1(Arka Ivory)	13.01	6.69	200.67
T_2(Arka Pride)	14.73	8.08	188.33
T_3(Arka Swadesh)	13.84	6.70	185.33
T_4(Gold Strike)	13.04	8.08	164.33
T_5 (Noblesse)	12.53	8.81	202.67
T_6 (Revival)	12.19	8.28	206.67
T_7(Taj Mahal)	12.60	10.52	197.00
T_8(Corvette)	13.62	8.89	198.00
T_9(Emma)	11.73	9.60	196.33
T_{10}(Peach Avalanche)	15.11	9.48	200.00
CD @ (0.05)	**1.32**	**NS**	**NS**
CV	**5.84**	**16.88**	**10.26**

4.3.1.1.2. Flower persistence (days)

Regarding flower persistence of cut flower varieties, no significant variation could be observed during the period of observation.

4.3.1.1.3. Duration of flowering (days)

There was no significant variation in duration of flowering of cut flower varieties.

4.3.1.2. Floral characteristics

The floral parameters of cut flower varieties are given in Table 11.

4.3.1.2.1. Length of flower bud (cm)

The length of the flower bud varied significantly among the varieties and the varieties Arka Ivory (2.77 cm), Taj Mahal (2.53) and Arka Swadesh (2.53 cm) were performing on par with longest flower buds. The shortest bud was observed in the variety Peach Avalanche (2.03 cm).

4.3.1.2.2. Diameter of the flower bud (cm)

Significant variation could be observed in diameter of flower bud and the varieties Gold Strike, Taj Mahal, Arka Ivory and Arka Pride were superior in terms of this parameter (1.24cm, 1.21 cm, 1.09 cm and 1.08 cm respectively). The lowest flower bud diameter was observed in variety Corvette (0.76 cm).

4.3.1.2.3. Number of petals per flower

There was significant variation in number of petals per flower and highest number of petals were observed in variety Taj Mahal (79.54) followed by Noblesse (38.2), Peach Avalanche (33.68) and Emma (30.33). The lowest number of petals was observed in Arka Pride (17.87) and Corvette (18.83) which were performing on par.

Table 11. Floral parameters of cut flower varieties

Variety	Length of flower bud(cm)	Diameter of flower bud (cm)	Number of petals per flower	Flower diameter at fully opened stage (cm)	Length of the flower shoot (cm)	Thickness of flower shoot (cm)	Length of neck (cm)	Girth of neck (cm)	Length of flower stalk (cm)	Girth of the flower stalk (cm)	Number of flowers per sprout	Number of flowers per plant	Number of marketable flowers
T_1(Arka Ivory)	2.77	1.09	22.82	6.54	18.99	0.24	5.46	1.67	24.45	2.50	6.03	11.38	8.45
T_2(Arka Pride)	2.35	1.08	17.87	5.78	24.11	0.26	6.37	1.65	30.48	2.37	5.90	6.20	4.97
T_3(Arka Swadesh)	2.53	1.05	25.61	5.71	19.16	0.23	6.61	1.75	25.78	2.23	10.10	10.10	6.62
T_4(Gold Strike)	2.31	1.24	27.72	5.70	17.53	0.24	4.31	1.50	21.84	2.07	4.46	8.93	6.07
T_5 (Noblesse)	2.28	1.11	38.92	6.02	20.54	0.25	5.46	1.67	25.99	2.57	7.85	7.85	6.25
T_6 (Revival)	2.23	1.05	20.25	5.41	17.01	0.22	5.07	1.47	23.85	2.37	14.37	12.45	7.23
T_7 (Taj Mahal)	2.53	1.21	79.54	6.23	18.65	0.25	5.00	1.77	24.50	2.73	9.42	9.75	8.28
T_8(Corvette)	2.08	0.76	18.83	5.07	16.92	0.15	6.38	1.65	23.29	2.30	4.65	4.65	3.07
T_9(Emma)	2.45	0.90	30.33	6.02	23.99	0.22	7.36	1.63	31.35	2.10	5.28	5.28	3.32
T_{10}(Peach Avalanche)	2.03	1.01	33.68	5.75	21.51	0.24	5.73	1.45	25.73	2.23	4.93	9.87	6.58
CD (5%)	**0.38**	**0.16**	**9.18**	**NS**	**NS**	**NS**	**0.77**	**NS**	**NS**	**NS**	**1.26**	**2.67**	**1.27**
CV	**9.53**	**9.04**	**17.07**	**9.53**	**16.45**	**14.72**	**7.81**	**8.57**	**16.45**	**11.77**	**10.16**	**18.15**	**12.21**

No significant variation could be observed in flower diameter of varieties at fully opened stage.

4.3.1.2.5. Length of flower shoot (cm)

There was no significant variation in length of flower shoot of varieties during the period of observation.

4.3.1.2.6. Thickness of flower shoot (cm)

No significant difference could be observed in the thickness of the flower shoot among the cut flower varieties which was at a range of 0.15cm- 0.26 cm.

4.3.1.2.7. Neck length (cm)

Neck length varied significantly among varieties. Lowest neck length was observed in Gold Strike (4.31 cm). The varieties Emma and Arka Swadesh were performing on par with highest neck length (7.36 cm and 6.61 cm respectively).

4.3.1.2.8. Neck girth (cm)

The neck girth of the varieties not differed significantly which were in the range of 1.47 cm -1.75 cm.

4.3.2.9. Stalk Length of the flower (cm)

There was significant variation in stalk length of cut flower varieties. Highest stalk length was observed in varieties Emma and Arka Pride (31.35 cm and 30.48 cm) which were performing on par with each other and stalk length was lowest in Gold Strike (21.84 cm).

4.3.1.2.10. Girth of flower stalk

There was no significant variation in girth of flower stalk of cut flower varieties during the period of observation.

4.3.1.2.11. Number of flowers per sprout

The number of flowers per sprout varied significantly among the varieties and the variety Revival (14.36) had highest number of flowers per sprout. The lowest number of flowers per sprout was observed in variety Gold Strike (4.46).

4.3.1.2.12. Number of flowers per plant

Significant variations in number of flowers per plant were observed in cut flower varieties with highest number of flowers in varieties Revival (12.45), Arka Ivory (11.38), Arka Swadesh (10.10) and Peach Avalanche (9.86) which were performing on par. The lowest numbers of flowers were observed in Corvette (4.65).

4.3.1.1.13. Number of marketable flowers

The yield of marketable flowers varied significantly among the cut flower varieties. The varieties Arka Ivory (8.45) and Taj Mahal (8.23), were performing on par with highest number of marketable flowers. The lowest number of marketable flowers was observed in Corvette (6.56).

The highest numbers of quality flowers were produced during the months of November- December in all the varieties except Noblesse and Gold Strike where highest numbers of quality flowers were produced during January (Table 12). All the varieties produced highest number of marketable flowers during the months of December. Arka Ivory produced more number of quality flowers even during the hot months of February- March. Arka Pride was not having any significant difference in flower production over different months. Revival and Taj Mahal produced quality flowers throughout the growing period highest being in December.

4.3.1.3. Post-harvest studies

Table 12. Number of marketable flowers over months in cut flower varieties

	Arka Ivory	Arka Pride	Arka Swadesh	Gold Strike	Noblesse	Revival	Taj Mahal	Corvette	Emma	Peach Avalanche
September	1.17	1.00	1.00	1.00	1.25	1.92	1.56	0.50	1.32	1.47
October	1.33	1.00	1.00	1.75	1.50	1.17	1.00	1.08	1.41	2.08
November	1.30	1.00	1.97	1.52	2.08	2.40	1.47	0.92	1.17	2.00
December	3.05	1.17	2.70	1.67	1.75	4.57	1.80	1.17	1.32	2.39
January	1.50	1.00	1.63	2.27	2.25	1.00	1.72	1.00	0.92	1.00
February	2.00	1.00	0.33	0.50	1.08	1.18	1.23	0.92	0.75	1.27
March	2.17	1.00	0.53	0.83	0.92	1.25	1.33	0.75	0.63	1.10
CD (5 %)	**0.48**	**NS**	**0.22**	**0.37**	**0.47**	**0.46**	**0.39**	**0.30**	**0.32**	**0.31**
CV	**15.32**	**10.66**	**9.72**	**15.44**	**17.27**	**13.75**	**16.82**	**19.07**	**17.22**	**10.88**

The post-harvest characters of cut flower varieties are given in Table 13.

4.3.1.3.1. Fresh weight of the flower

The fresh weight of the flowers varied significantly among the cut flower varieties and the highest fresh weight was observed in variety Taj Mahal (8.08 g) and Noblesse (7.84 g) which were performing on par with each other. The least fresh weight was observed in variety Corvette (2.58 g).

4.3.1.3.2. Physiological loss in weight

There was significant difference in the physiological loss in weight. Arka Pride had lowest (1.68 g) physiological loss in weight. Arka Ivory, Revival, Taj Mahal, Peach Avalanche, Gold Strike and Arka Swadesh recorded highest value in terms of this parameter (3.35 g, 3.25 g, 2.97 g, 2.94 g, 2.75 g and 2.73 g respectively).

4.3.1.3.3. Total water uptake (ml)

The variety Arka Ivory reported highest water uptake (34.88 ml) and lowest water uptake was observed in variety Gold Strike (2.62 ml).

4.3.1.3.4. Vase life

The vase life differed significantly among the cultivars and vase life was highest in varieties Revival (4.83 days), Taj Mahal (4.75 days) and Noblesse (4.75 days) and lowest in variety Corvette (2.5 days) (Plate 7).

4.3.1.5. Qualitative characters

The qualitative floral characters of cut flower varieties are represented in Table 14.

4.3.1.5.1. Flower colour

Plate 7. Cut flower varieties during vase life study

Table 13. Post harvest characteristics of cut flower varieties

Variety	Fresh weight of the flower (g)	Physiological loss in weight (g)	Total water uptake (ml)	Vase life (days)
T_1(Arka Ivory)	6.31	3.35	34.88	2.73
T_2(Arka Pride)	5.03	1.68	16.00	3.58
T_3(Arka Swadesh)	5.40	2.73	17.49	2.92
T_4(Gold Strike)	4.01	2.75	11.22	3.61
T_5 (Noblesse)	7.84	2.56	19.33	4.75
T_6 (Revival)	5.99	3.23	13.33	4.83
T_7(Taj Mahal)	8.08	2.97	25.00	4.75
T_8(Corvette)	2.58	2.58	19.07	2.50
T_9(Emma)	4.32	2.04	25.33	3.92
T_{10}(Peach Avalanche)	6.63	2.94	21.83	4.30
CD(0.05)	**1.00**	**0.71**	**2.62**	**0.67**
CV	**10.41**	**15.51**	**7.57**	**10.39**

Table 14. Qualitative characters of cut flower varieties (Floral)

Variety	Flower colour	Inflorescence type	Number of thorns per 10 cm of stalk length	Fragrance	Absence of blemishes and overall appearance
T_1(Arka Ivory)	RHS 2015 159 D (PaleYellowish pink)	Solitary and clustered	Many	Medium	Good
T_2(Arka Pride)	RHS 2015 33C (Strong yellowish pink)	Solitary and clustered	Medium	Medium	Fair
T_3(Arka Swadesh)	RHS 2015 52 A (Vivid Red)	Solitary and clustered	Medium	Weak	Fair
T_4(Gold Strike)	RHS 2015 9 A (Vivid yellow)	Solitary	Medium	Medium	Fair
T_5 (Noblesse)	RHS 2015 38 A (Strong yellowish pink)	Solitary	Medium	Medium	Good
T_6 (Revival)	RHS 2015 73 A (Deep purplish pink)	Solitary	Weak	Weak	Good
T_7(Taj Mahal)	RHS 2015 46 B (Vivid Red)	Solitary and clustered	Weak	Weak	Excellent
T_8(Corvette)	RHS 2015 31 B (Strong reddish orange)	Solitary	Many	Weak	Poor
T_9(Emma)	RHS 2015 56 C(Pale purplish pink)	Solitary	Absent	Weak	Fair
T_{10}(Peach Avalanche)	RHS 2015 27 A (Light yellowish pink)	Solitary and clustered	Weak	Weak	Good

Rating scale

- **Flower colour:** White blend-1, Yellow blend-2, Orange blend-3, Pink blend-4, Red blend-5.
- **Inflorescence type**: Solitary or Clustered.
- **Number of thorns per 10cm of stalk length**: Absent -1, Few-3, Medium-5, Many-7.
- **Fragrance**: Absent-1,Weak-3, Medium -5, Strong-7
- **Absence of blemishes and overall appearance**: Excellent -5, Good- 4,Fair -3 , Average -2 ,Poor -1

87

Flower colour was recorded as per RHS colour chart 2015. The varieties evaluated were categorised under different colour groups according to DUS guidelines for rose as pink, yellow, orange and red. Variety Gold Strike was categorised under vivid yellow group colour code of RHS 2015 9 A. Variety Corvette was found to come under the category of strong reddish orange group of RHS 31 B colour code. Variation in flower colour of pink group ranged from light yellowish pink in Peach Avalanche (RHS 2015 27 A), pale purplish pink in Emma (RHS 2015 56 C), yellowish pink in Arka Ivory (RHS 2015 159 D) and strong yellowish pink in Arka Pride (RHS 2015 33C).

4.3.1.5.2. Inflorescence type

The varieties Gold Strike, Noblesse, Revival, Peach Avalanche and Emma produced solitary flowers while solitary sometimes clustered flowers were produced in the varieties Arka Ivory, Arka Pride, Arka Swadesh, TajMahal and Corvette.

4.3.1.5.3. Number of thorns per 10 cm stalk length

The number of thorns present in flower stalks was relatively lower as compared to vegetative shoots and high amount of thorns (7) were noticed in variety Arka Ivory, and Corvette followed by few thorns (5) in Arka Pride, Arka Swadesh and Noblesse. Gold Strike, Peach Avalanche, Revival and Taj Mahal were observed to have very few amounts of thorns (3). Variety Emma was reported as a variety without any thorns (1) on stalk.

4.3.1.5.4. Fragrance

The varieties Arka Ivory, Arka Pride, Gold Strike and Noblesse were found to have medium fragrance (5) whereas varieties Taj Mahal, Revival, Arka Ivory and Peach Avalanche were having weak fragrance (3) and Emma and Corvette without fragrance (1).

4.3.1.5.5. Absence of blemishes and overall appearance

All varieties were devoid of any blemishes and the variety Taj Mahal scored an excellent score (5) of overall acceptability due to its highest number of petals, flower persistence, colour, vase life and overall appearance. The varieties Arka Ivory, Revival, Peach Avalanche and Gold Strike had scored an overall acceptability of good (4) due to its highest number of quality flowers and Noblesse due to its number of petals, vase life and characteristic appearance like cut flower. Due to the lower vase life and less number of petals the varieties, Arka Pride and Arka Swadesh scored fair (3) in acceptability whereas variety Corvette was poor (1) in appearance.

4.3.1.6. Overall performance of cut flower varieties

The overall performance of cut flower varieties were assessed based on the quality attributes like length and diameter of flower bud, number of petals, stalk length, vase life and number of marketable flowers produced per plant and is represented in Table 15.

The variety Taj Mahal scored the highest rank (1) as the variety was having highest length (2.53 cm) and diameter (1.21 cm) of flower bud, highest number of petals (79), vase life (4.75 days) and more number of marketable flowers (8.28). The variety Noblesse scored a rank of 2 due to its more number of petals (38.92), high vase life and more number of marketable flowers (7.23). The varieties Arka Pride and Corvette scored the least rank (5) mainly due to the lowest number of petals (17.87, 18.83 respectively) and lowest number of marketable flowers (4.97, 3.32 respectively).

4.4. Correlation study in cut flower varieties

The correlations between various vegetative, floral and meteorological observations were represented in Table 16.

Table 15. Overall performance of cut flower varieties

Variety	Stalk length (cm)	Number of petals	Length of bud (cm)	Diameter of bud	Vase life	Number of marketable flowers	Score	Rank
T_1(Arka Ivory)	2	3	1	2	3	1	13	4
T_2(Arka Pride)	1	4	2	2	2	2	14	5
T_3(Arka Swadesh)	2	3	1	2	3	1	13	4
T_4(Gold Strike)	2	3	2	2	2	1	13	4
T_5 (Noblesse)	2	2	2	2	1	1	11	2
T_6 (Revival)	2	3	2	2	1	1	12	3
T_7(Taj Mahal)	2	1	1	2	1	1	9	1
T_8(Corvette)	2	4	1	2	3	2	14	5
T_9(Emma)	1	2	1	2	2	2	12	3
T_{10}(Peach Avalanche)	2	2	1	2	3	1	12	3

Overall performance- score card

Stalk length (cm)	Number of petals	Length of flower bud (cm)	Diameter of flower bud (cm)	Vase life (days)	Number of marketable flowers
> 30 - 1 20-30- 2	40-1 30-40-2 20-30-3 10-20-4	2-3 -1 1-2 - 2 <1 -3	1-2- 1	4-5- 1 3-4-2 2-3-3 1-2-4	5-10- 1 1-5 - 2

Table 16. Correlation with vegetative, floral and meteorological parameters in rose

	NF	LB	DB	NP	FD	SL	ST	NL	PH	PS1	PS2	NS	NB	NL	Temp	RH	PAR
NF	1																
LB	0.161^{NS}																
DB	0.008^{NS}	0.395**															
NP	0.209^{NS}	-0.183^{NS}	0.142^{NS}														
FD	0.078^{NS}	-0.236*	-0.087^{NS}	0.345**													
SL	-0.435**	0.032^{NS}	-0.006^{NS}	-0.019^{NS}	0.243*												
ST	0.431**	-0.060^{NS}	-0.311**	-0.181^{NS}	-0.042^{NS}	-0.267*											
NL	-0.295*	0.034^{NS}	-0.239*	-0.218^{NS}	0.159^{NS}	0.374**	-0.194^{NS}										
PH	0.391**	0.163^{NS}	0.357**	0.194^{NS}	-0.032^{NS}	-0.100^{NS}	-0.038^{NS}	-0.296*									
PS1	0.385**	0.221^{NS}	0.178^{NS}	-0.135^{NS}	-0.028^{NS}	-0.206^{NS}	0.419**	-0.224^{NS}	0.507**								
PS2	0.329**	0.161^{NS}	0.389**	-0.014^{NS}	-0.084^{NS}	-0.284*	0.358**	-0.356**	0.452**	0.718**							
NS	0.519**	0.191^{NS}	-0.011^{NS}	-0.010^{NS}	-0.014^{NS}	-0.466**	0.648**	-0.397**	0.301*	0.531**	0.467**						
NB	0.448**	0.293*	0.151^{NS}	0.051^{NS}	-0.226^{NS}	-0.357**	0.279*	-0.182^{NS}	0.384**	0.566**	0.552**	0.428**					
NL	-0.214^{NS}	-0.313**	-0.206^{NS}	-0.060^{NS}	0.304*	0.309**	0.112^{NS}	-0.004^{NS}	-0.158^{NS}	-0.038^{NS}	-0.008^{NS}	-0.087^{NS}	0.516^{NS}				
Temp	-0.181**	0.194^{NS}	0.209^{NS}	-0.450**	-0.172^{NS}	-0.346**	0.132^{NS}	-0.173**	0.286*	0.364**	0.466**	0.344**	0.466**	-0.326**			
RH	-0.224^{NS}	-0.298*	-0.344**	0.071^{NS}	0.228^{NS}	0.294*	-0.146^{NS}	0.399**	-0.540**	-0.472**	-0.524**	-0.407**	-0.435**	0.366**	-0.688**		
PAR	-0.156^{NS}	0.139^{NS}	0.113^{NS}	0.341**	0.056^{NS}	0.005^{NS}	0.008^{NS}	0.025^{NS}	-0.032^{NS}	0.166^{NS}	0.060^{NS}	0.022^{NS}	-0.073^{NS}	-0.069^{NS}	0.508**	-0.479**	1

***Significant at 1 % level, ** Significant at 5 % level**

NF-Number of flowers, LB- Length of flower bud, DB- Diameter of flower bud, NP- Number of petals, FD-Flower diameter, SL- Stalk length, ST- Stalk thickness, NL- Neck length, PH- Plant height, PS1- Plant spread (N-S), PS2-Plant spread(E-W),NS- Number of sprouts, NB- Number of branches, NL- Neck length, Temp-Temperature, RH- Relative humidity, PAR-Photosynthetically active radiation

4.4.1.1. Correlation between vegetative characters

Plant spread in NS and EW directions was positively and significantly correlated with number of sprouts (0.531, 0.467 respectively) and number of branches (0.566, 0.552 respectively). There was a significant and positive correlation with number of sprouts and number of branches (0.428). No significant correlation could be observed between number of leaves and other vegetative parameters.

4.4.1.2. Correlation between floral characters

There was a significant and positive correlation between number of flowers and stalk thickness (0.431). Length of flower bud was significantly and positively correlated with diameter of flower bud (0.395), whereas a negative correlation could be observed between diameter of flower bud and stalk thickness (-0.311). A significant and positive correlation of flower diameter was observed with number of petals (0.345) and stalk length (0.243). Neck length was positively correlated with stalk length (0.374) whereas a negative correlation of neck length could be observed with number of flowers (-0.295).

4.5.1.3. Correlation between vegetative and floral characters

Plant height was significantly and positively correlated with number of flowers (0.391) whereas a negative correlation was observed between plant height and neck length (-0.296). A positive correlation of plant spread in N-S and E-W directions could be observed with number of flower (0.385, 0.329 respectively) and flower diameter (-0.28,-0.084 respectively) and a negative correlation of plant spread (E-W) was observed with neck length (-0.356). A significant and positive correlation was observed between number of sprouts and number of flowers (0.519) and there was a negative correlation of number of sprouts with stalk length (-0.466). Number of leaves was significantly and positively correlated with stalk length (0.309) and flower

diameter (0.243). A negative correlation was observed between number of leaves and length of flower bud (-0.313).

4.5.1.4. Correlation between meteorological parameters, vegetative and floral characters

Temperature was positively and significantly correlated with vegetative parameters like plant height (0.286), plant spread in N-S and E-W directions (0.364,0.466), number of sprouts (0.344) and number of branches (0.466) whereas negative correlation was observed between temperature and number of leaves (-0.326). A negative correlation of temperature could be observed with number of flowers (-0.181), number of petals (-0.450) and stalk length (-0.346). Relative humidity was negatively correlated with plant height (-0.540), plant spread in E-W (-0.472) and N-S (-0.524) directions, number of sprouts (-0.407) and number of branches (-0.435). A negative correlation of relative humidity were also observed with floral characters like length of flower bud (-0.298) and diameter of flower bud (-0.344) and a significant positive correlation was observed between relative humidity and neck length (0.399). There was a significant positive correlation could be observed between PAR and number of petals (0.341). No significant correlation could be observed between PAR and other vegetative or floral parameters.

4.3.2. Loose flowers

4.3.2.1. Flowering characteristics

Data pertaining to flowering characteristics are furnished in Table 17.

4.3.2.1.1. Days taken from emergence to opening of flower buds

Among loose flower varieties, lowest numbers of days from initiation to opening of flower buds were observed in varieties Charisma, Spray Yellow, Spray Orange, Star Light, Mirabel and ArkaParimala (13.03, 13.08, 13.36, 13.7, 13.75, 14.8

Table 17. Flowering characteristics of loose varieties

Variety	Days taken for initiation to opening of flower buds	Flower persistence (Days)	Duration of flowering (Days)
T1 (ArkaParimala)	14.1	5.4	199.3
T2 (Sherba Gold)	15.1	12.0	180.0
T3 (Mirabel)	13.8	9.6	200.7
T4 (Vernish)	14.9	8.9	197.3
T5 (Charisma)	13.0	11.4	201.7
T6 (Jadiov)	16.6	8.9	182.3
T7 (Star Light)	13.4	8.6	191.7
T8 (Spray Orange)	13.7	6.7	203.7
T9 (Spray Yellow)	13.1	7.2	173.3
T10 (Red Varnish)	15.1	8.4	202.0
CD (5%)	**1.8**	**2.7**	**19.7**
CV	**7.26**	**18.39**	**5.98**

respectively) which were performing on par with each other whereas the variety Jadiov took highest number of days for flower initiation to opening of flower buds (16.6 days).

4.3.1.1.2. Flower persistence (days)

The flower persistence of loose flower varieties varied significantly and the longest flower persistence was observed in varieties Sherba Gold, Mirabel and Charisma, (11.96, 11.37, and 9.55) which were performing on par with each other. The shortest flower persistence was observed in ArkaParimala (5.38 days).

4.3.2.1.3..Duration of flowering

Varieties differed significantly in duration of flowering and highest duration of flowering was observed in varieties Spray Orange, Red Varnish, Charisma, Mirabel, ArkaParimala, Vernish and Star Light (203.7,202,201.7,200.7,199.3,197.3 and 191.7 days respectively) which were performing on par with each other.

4.3.2.2. Floral parameters

The floral parameters are represented in Table 18.

4.3.2.2.1. Length of flower bud

Among loose flower varieties significant differences in length of flower bud was observed and the variety ArkaParimala recorded highest bud length (2.63 cm) and lowest length of flower bud was observed in Star Light (1.6 cm).

4.3.2.2.2. Diameter of flower bud

The highest diameter of flower bud was observed in variety Sherba Gold (1.03 cm), Charisma (9.06 cm), Star Light (0.92 cm) and Vernish (0.92 cm) which were performing on par with each other. Lowest flower bud diameter was observed in Spray Orange (0.69 cm).

Table 18. Floral parameters of loose flower varieties

Variety	Length of flower bud (cm)	Diameter of flower bud (cm)	Number of petals per flower	Flower diameter at fully opened stage (cm)	Number of flowers per sprout	Number of flowers per plant	Yield of marketable flowers (g/plant)
T1 (ArkaParimala)	2.6	1.00	15.4	6.7	6.48	14.53	34.33
T_2 (Sherba Gold)	2.1	1.03	61.5	4.1	5.64	11.28	17.62
T_3 (Mirabel)	1.9	0.71	40.7	3.2	20.55	24.20	20.83
T_4 (Vernish)	1.8	0.90	35.7	4.1	20.82	21.33	28.39
T_5 (Charisma)	1.9	0.96	57.5	3.9	6.87	20.60	28.70
T_6 (Jadiov)	1.8	0.83	21.3	3.9	5.41	12.78	11.29
T_7 (Star Light)	1.6	0.92	101.0	4.8	3.32	10.02	18.93
T_8 (Spray Orange)	1.7	0.69	37.3	3.4	18.60	20.53	26.93
T_9 (Spray Yellow)	1.7	0.72	37.6	2.8	17.98	19.80	13.99
T_{10} (Red Varnish)	1.9	0.80	32.3	3.4	8.40	27.80	29.28
CD (5%)	**0.2**	**0.18**	**3.2**	**0.9**	**6.04**	**2.75**	**5.29**
CV	**6.6**	**12.2**	**4.2**	**12.38**	**7.26**	**8.84**	**13.48**

4.3.2.2.3. Number of petals per flower

Significant differences in number of petals were observed among loose flower varieties and the variety Star Light recorded highest number of petals (101.0). The lowest numbers of petals were observed in variety ArkaParimala (15.4).

4.3.2.2.4. Flower diameter at fully opened stage

The loose flower varieties showed significant difference in flower diameter at fully opened stage. Arka Parimala recorded highest flower diameter (6.67 cm) followed by Star Light (4.84 cm), Sherba Gold (4.13 cm) and Vernish (4.09 cm). The lowest flower diameter was observed in Spray Yellow (2.83 cm).

4.3.2.2.5. Number of flowers per sprout

Significant variation in number of flowers per sprout was observed among loose flower varieties and highest number of flowers per sprout was observed in Vernish (20.82), Mirabel (20.55), Spray Orange (18.6) and Spray Yellow (17.98) which were performing on par with each other. The least number was reported in Star Light (3.31).

4.3.2.2.6. Number of flowers per plant

Regarding number of flowers per plant, the variety Red Varnish (27.8) had highest numbers of flowers followed by Mirabel (24.2). The lowest number of flowers was observed in Star Light (9.95).

4.3.2.2.7. Yield of marketable flowers

Highest yield of marketable flowers was observed in variety Arka Parimala (34.33 g) whereas the lowest marketable yield was obtained in variety Jadiov (11.39 g).

Yield of marketable flowers produced in different months are represented in Table 19 and it indicates that highest marketable yield of flowers were obtained during the month of December.

4.3.2.3. Post harvest studies

Data pertaining to the post harvest characters are furnished in Table 20.

4.3.2.3.1. Fresh weight of the flower (g)

The fresh weight of the flower significantly varied among the loose flower varieties and highest fresh weight was observed in the variety Star Light (3.16 g) and Arka Parimala (3.14 g) followed by Sherba Gold (2.64). The least fresh weight was recorded in variety Spray Yellow (1.13 g).

4.3.4.2.2. Number of petals per flower

Significant differences in number of petals were observed among loose flower varieties and the variety Star Light recorded highest number of petals (101.0). The lowest numbers of petals was observed in variety Arka Parimala (15.4).

4.3.4.2.3. Weight of petals per flower (g)

Weight of petals significantly differed among the loose flower varieties and highest weight of petals was observed in variety Star Light (2.78 g), followed by Arka Parimala (1.94 g) and Sherba Gold (1.83 g). The least petal weight was observed in variety Spray Yellow (0.683 g).

4.3.4.2.4. Shelf life

Regarding shelf life, no significant variation could be observed among the varieties (Plate 8).

4.3.2.5. Qualitative characters

Plate 8. Loose flower varieties during shelf life study

Table 19. Marketable flower yield over months in loose flower varieties

Months	Varieties									
	Arka Parimala	Sherba Gold	Mirabel	Vernish	Charisma	Jadiov	Star Light	Spray Orange	Spray Yellow	Red Varnish
September	3.35	3.43	3.66	3.72	3.08	2.27	4.74	1.87	1.30	3.55
October	5.76	4.40	3.61	2.26	2.73	2.57	4.53	2.61	1.89	3.73
November	5.45	6.34	6.28	4.82	5.74	3.01	4.74	3.88	2.42	4.40
December	10.11	14.78	11.16	10.19	7.55	4.82	6.11	9.51	10.86	8.60
January	5.45	3.96	3.97	5.57	4.92	3.81	5.16	5.13	5.67	7.40
February	3.93	3.52	4.15	3.98	2.66	2.07	1.84	3.63	1.70	5.91
March	3.14	2.64	3.51	3.98	3.35	2.27	2.11	2.89	1.51	2.77
CD (5 %)	**0.84**	**1.41**	**1.11**	**1.20**	**0.86**	**0.43**	**1.14**	**0.67**	**0.75**	**0.86**
CV	**9.06**	**14.38**	**12.24**	**13.88**	**11.49**	**8.28**	**15.60**	**9.06**	**11.88**	**9.43**

Table 20. Post harvest characteristics loose flower varieties

Variety	Fresh weight of the flower (g)	Number of petals per flower	Weight of petals (g)	Shelf life (days)
T1 (ArkaParimala)	3.14	15.40	1.95	1.00
T2 (Sherba Gold)	2.64	61.47	1.83	1.00
T3 (Mirabel)	1.83	40.73	1.21	1.00
T4 (Vernish)	1.59	35.67	1.02	1.00
T5 (Charisma)	1.68	57.46	1.07	1.00
T6 (Jadiov)	1.77	21.33	1.17	1.00
T7 (Star Light)	3.16	101.00	2.79	1.00
T8 (Spray Orange)	1.49	37.33	0.77	1.00
T9 (Spray Yellow)	1.13	37.55	0.68	1.00
T10 (Red Varnish)	1.57	32.33	0.92	1.00
CD(0.05)	**0.30**	**3.15**	**0.45**	**NS**
CV	**8.89**	**4.20**	**19.62**	

The qualitative characters of and loose flower varieties are represented in Table 21.

4.3.2.5.1. Flower colour

Loose flower varieties were categorised under different groups of colours *viz.* yellow, orange and red as per RHS colour chart and DUS guidelines. Flower colour was vivid yellow in varieties Sherba Gold and Spray Yellow (RHS 2015 12 A and RHS 2015 B respectively). The varieties Mirabel and Jadiov were having vivid reddish orange (RHS 2015 44 B) whereas spray Orange was categorised under strong reddish orange (RHS 2015 32 B). Vivid red colour (RHS 2015 58 B) was observed in variety Red Varnish while the varieties Arka Parimala and Star Light were having strong purplish red colour. Double coloured petals having vivid orange distal end (RHS 2015 28 B) and vivid yellow at proximal end (RHS 2015 17 B) were noticed in variety Charisma.

4.3.2.5.2. Inflorescence type

The varieties Arka Parimala, Jadiov and Star Light produced solitary flowers while Sherba Gold, Mirabel, Vernish, Charisma, Spray Orange and Spray Yellow were having solitary and clustered flowers.

4.3.2.5.3. Number of thorns per 10 cm stalk length

Number of thorns per 10 cm stalk length was negligible in all forms of loose flower varieties.

4.3.2.5.4. Fragrance

In the case of loose flower varieties Arka Parimala was categorised as highly fragrant (7) and medium fragrance was observed in Star Light and Charisma (5) whereas varieties Sherba Gold, Mirabel, Spray yellow and Spray Orange were varieties

Table 21. Qualitative characters of loose flower varieties (Floral)

Variety	Flower colour	Inflorescence type	Number of thorns per 10 cm of stalk length	Fragrance	Absence of blemishes and overall appearance
T1 (ArkaParimala)	RHS 2015 58 C (Strong purplish red)	Solitary	Absent	Strong	Good
T2 (Sherba Gold)	RHS 2015 12 A (Vivid yellow)	Solitary and clustered	Absent	Weak	Good
T3 (Mirabel)	RHS 2015 44 B (Vivid reddish orange)	Solitary and clustered	Absent	Weak	Good
T4 (Vernish)	(Vivid red)RHS 2015 52 A	Solitary and clustered	Absent	Absent	Good
T5 (Charisma)	Distal end RHS 2015 28 B (Vivid orange) proximal end RHS 2015 17 B (Vivid yellow)	Solitary and clustered	Absent	Medium	Excellent
T6 (Jadiov)	RHS 2015 N 30 C Vivid reddish orange	Solitary	Absent	Absent	Good
T7 (Star Light)	RHS 2015 58 B (Strong purplish red)	Solitary	Absent	Medium	Excellent
T8 (Spray Orange)	RHS 2015 32 B (Strong reddish orange)	Solitary and clustered	Absent	Weak	Good
T9 (Spray Yellow)	RHS 2015 12 B (Brilliant yellow)	Solitary and clustered	Absent	Weak	Good
T10 (Red Varnish)	RHS 2015 45 B (Vivid red)	Solitary and clustered	Absent	Absent	Good

Rating Scale

- **Flower colour**: White blend-1, Yellow blend-2, Orange blend-3, Pink blend-4, Red blend-5.
- **Inflorescence type**: Solitary or Clustered.
- **Number of thorns per 10cm of stalk length**: Absent -1, Few-3, Medium-5, Many-7.
- **Fragrance**: 1- highly fragrant, 2- medium fragrant, 3- less fragrant, 4- no fragrance
- **Absence of blemishes and overall appearance** : Excellent -5, Good- 4, Fair-3, Average -2 ,Poor -1

with weak fragrance (3). Varieties Vernish, Jadiov and Red varnish were without any fragrance (1).

4.3.2.5.5. Absence of blemishes and overall appearance

Among loose flower varieties, the varieties Charisma and Star Light scored an overall acceptability of score excellent (5) due to characteristic fragrance and more number of flowers. All other varieties were scored good (3).

4.3.2.6. Overall performance of loose flower varieties

The overall performance of loose flower varieties were assessed based on quality attributes like number of petals, flower diameter, fragrance and yield of marketable flowers. The performances of the varieties are given in Table 22.

The variety Star Light scored highest rank (1) due to its higher number of petals (102) and flower diameter (4.8 cm). This was followed by the varieties Arka Parimala due to its strong fragrance, highest flower diameter (6.7) and marketable yield per plant (34.33), Sherba Gold due to its more number of petals (61.5) and flower diameter (4.1 cm), Charisma due to its medium fragrance and marketable yield per plant. The lowest rank was recorded by Spray Yellow (5).

4.4.2. Correlation study in loose flower varieties

Correlations between various vegetative, floral and meteorological parameters are represented in Table 23.

4.4.2.1. Correlation between vegetative characters

Plant height was significantly and positively correlated with number of leaves (0.242) and a negative correlation of plant height was observed with plant spread in

Table 22. Overall performance of loose flower varieties

Variety	Number of petals	Fragrance	Flower diameter	Yield of marketable flowers	Score	Rank
T1 (ArkaParimala)	7	1	1	1	10	2
T2 (Sherba Gold)	2	3	2	3	10	2
T3 (Mirabel)	4	3	3	2	12	3
T4 (Vernish)	3	4	3	2	12	3
T5 (Charisma)	3	2	3	2	10	2
T6 (Jadiov)	6	4	3	3	16	6
T7 (Star Light)	1	2	2	3	8	1
T8 (Spray Orange)	5	3	3	2	13	4
T9 (Spray Yellow)	5	3	3	3	14	5
T10 (Red Varnish)	3	4	3	2	12	3

Overall performance – score card

Number of petals	Fragrance	Flower diameter (cm)	Number of marketable flowers
• 70- 1 • 60-70-2 • 50-60-3 • 40-50-4 • 30-40-5 • 20-30-6 • 10-20-7	• Strong -1 • Medium -2 • Weak -3 • Absent -4	• 6-7-1 • 4-5-2 • 2-3-3	• 30-40-1 • 20-30-2 • 10-20-3

Table 23. Correlation between vegetative, floral and meteorological parameters in loose flower varieties of rose

	NF	LB	DB	FD	NP	PH	PS1	PS2	NS	NB	NL	Temp	RH	PAR
NF														
LB	0.874**													
DB	0.338**	0.207^{NS}												
FD	0.171^{NS}	0.074^{NS}	0.895**											
NP	-0.596**	-0.525**	-0.278*	-0.175^{NS}										
PH	-0.228^{NS}	-0.167^{NS}	0.228^{NS}	0.535**	0.119^{NS}									
PS1	0.074^{NS}	0.079^{NS}	-0.419**	-0.589**	-0.099^{NS}	-0.562**								
PS2	0.297*	0.168^{NS}	-0.160^{NS}	-0.353**	-0.237*	-0.627**	0.743**							
NS	0.717**	0.550**	0.652**	0.492**	-0.575**	-0.219^{NS}	0.125^{NS}	0.478**						
NB	0.577**	0.329**	0.690**	0.526**	-0.531**	-0.196^{NS}	0.034^{NS}	0.385**	0.913**					
NL	-0.747**	-0.656**	-0.318**	-0.198^{NS}	0.613**	0.242*	-0.152^{NS}	-0.473**	-0.772**	-0.661**				
Temp	-0.779**	-0.672**	-0.442**	-0.216^{NS}	-0.525**	0.330**	-0.136^{NS}	-0.421**	-0.784**	-0.650**	0.689**			
RH	-0.710**	-0.615**	-0.796**	-0.741**	0.491**	-0.167^{NS}	0.281*	-0.004^{NS}	-0.775**	-0.711**	0.643**	0.683**		
PAR	-0.471**	-0.466**	-0.660**	-0.656**	0.327**	-0.261*	0.532**	0.320**	-0.527**	-0.467**	0.356**	0.444**	0.635**	

NF-No. of flowers, LB- Length of flower bud, DB- Diameter of flower bud, FD- Flower diameter, NP-Number of petals, PH- Plant height, PS1- Plant Spread (E-W), PS2 Plant Spread (N-S) NS- Number of sprouts, NB- Number of branches NL- Number of leaves Temp. Temperature, RH-. Relative humidity, PAR- Photosynthetically active radiation

E-W (-0.562) and N-S (-0.627). There was a positive correlation between number of sprouts and number of branches (0.913).

4.4.2.2. Correlation between floral characters

A significant and positive correlation of number of flowers was observed with length of flower bud (0.874) and diameter of flower bud (0.338) whereas there was a negative correlation between number of flowers and number of petals (-0.596). Number of petals was negatively correlated with length of flower bud (-0.525) and diameter of flower bud (-0.278). Diameter of flower bud was significantly and positively correlated with flower diameter (0.895).

4.4.2.3. Correlation between vegetative and floral characters

Plant height was significantly and positively correlated with flower diameter (0.535). A negative correlation of plant spread in EW directions could be observed with number of petals (-0.237). Number of branches was positively correlated with number of flowers (0.577), length of flower bud (0.329), diameter of flower bud (0.690) and flower diameter (0.526) whereas there was a negative correlation between number of branches and number of petals (-0.531). A negative correlation of number of leaves was observed with number of flowers (-0.747), length of flower bud (-0.656) and diameter of flower bud (-0.318) and number of leaves was positively correlated with number of petals (0.613).

4.4.2.4. Correlation between meteorological parameters, vegetative and floral characters

There was a significant positive correlation of temperature with plant height (0.330) and number of leaves (0.689) and a negative correlation was observed between temperature and other vegetative parameters like number of sprouts (-0.784) and number of branches (-0.650). A negative correlation of temperature could be observed with floral parameters like number of flowers (-0.779), length of flower bud

(-0.672), diameter of flower bud (-0.442) and number of petals (-0.525). Relative humidity was positively correlated with number of petals (0.491) and a negative correlation of relative humidity was observed number of sprouts (-0.775). A negative correlation of relative humidity could be observed with floral characters like number of flowers (-0.710), length of flower bud (-0.615), diameter of flower bud (-0.796) and flower diameter (-0.741) and it was positively correlated with number of petals (0.0.491). PAR was significantly and positively correlated with number of petals (0.327) and number of leaves (0.356). A negative correlation of PAR was observed with floral characters like number of flowers (-0.471), length of flower bud (-0.466), diameter of flower bud (-0.660) and flower diameter (-0.656).

4.5. INCIDENCE OF PESTS, DISEASES AND MALFORMATIONS

4.5.1. Pest incidence

4.5.1.1. Thrips

Severe infestation of thrips was noticed during the months of January to April. The sucking symptoms were observed in young shoots, lower leaves, and flower buds as well as fully opened flower. Loss of lustre of leaves and flower petals, colour change of petals and stunted appearance of plant were observed due to the attack of thrips. Among the varieties, Arka Ivory was found to be moderately tolerant to infestation (Plate 9).

An integrated approach by placing yellow sticky traps, spraying neem based pesticides and application of Spiromecifen @ 2ml per litre were practiced to control infestation.

4.5.1.2. Bud borers and leaf feeders

The IIHR varieties *viz.* Arka Ivory and Arka Swadesh were found to be susceptible to leaf feeding insects like *Spodoptera litura*, ash weevil and grass hopper

Thrips infested flower at different stages

Bud borer infestation

Leaf feeders

Plate 9. Pest incidence on rose varieties

as the leaves are more succulent than others. Bud borers were seen on the buds damaging the buds and flower eating semi looper caterpillars were also seen. Since the infestation could be identified at the earliest, they could be managed by spraying Ekalux @ 2ml per litre preventing further damage.

Infestation of *Spodoptera litura*, ash weevil (*Myllocerus sp.*) and grass hopper were noticed and varieties Arka Ivory and Arka Swadesh were found to be susceptible to these pests. The infestation of bud borers and flower eating semi looper caterpillars were also noticed rarely. All the infestation could be managed by the application of Quinalphos @ 2ml per litre.

4.5.2. Diseases

4.5.2.1. Leaf spots

Four different types of leaf spots were observed on rose varieties (Plate 10) and they are as follows.

4.5.2.1. a. Black spot

Black spot disease caused by *Diplocarpon rosea* was noticed during the months of October to January which was characterised by black spots surrounded by yellow halo on leaves, causing complete withering and defoliation. Cut flower varieties Arka Swadesh, Arka Pride, Arka Ivory, Revival and Gold Strike as well as loose flower varieties Red Varnish and Charisma were highly prone to this disease. This disease could be controlled by spraying Bavistin @ 1 g per litre at weekly intervals.

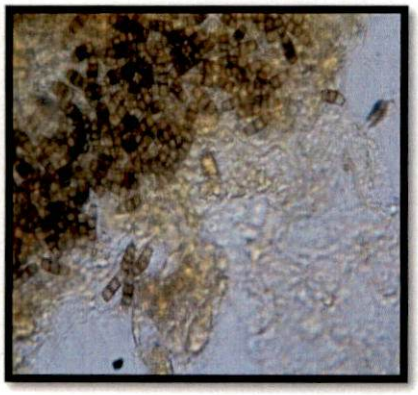
4.5.2.1. b. Alternaria leaf spot

The leaf spot caused by *Alternaria sp.* was observed on all varieties and on cut flower varieties Arka Ivory, Arka Swadesh, Taj Mahal and Corvette during the months of March and April and could be managed by spraying Carbendazim + Dithane-M-45 @ 2g per litre.

Black spot

Diplocarpon rosea

Leaf spot



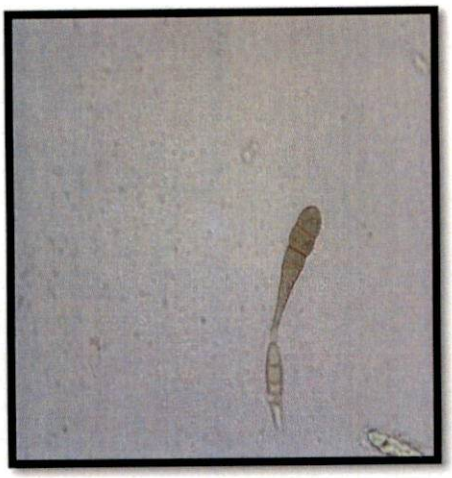
Pestalotia sp.

Leaf spot

Colletotrichum sp.

Plate 10 a. Diseases and causative organism on rose varieties

Alternaria spot



Alternaria sp.

Crown gall - *Agrobacterium rhizogenes*

Plate 10 b. Diseases and causative organism on rose varieties

4.5.2.1. c. Colletotrichum leaf spot

The disease caused by *Colletotrichum sp*. was seen in Arka Ivory during the months of October, Janauary and February. It could be managed by spraying Carbendazim @ 1g per litre.

4.5.2.1. d. Pestalotia leaf spot

The disease caused by *Pestalotia sp*. was observed in all varieties and it was severe in Merabel and Spray Yellow during the months of October- November. It could be managed by spraying Carbendazim@1 g per litre.

4.5.2..2. Crown gall

The disease was caused by *Agrobacterium rhizogenes* and observed during November in the varieties Gold Strike and Vernish. The disease could be controlled by removal of affected plant parts and isolation of the plants.

4.5.3. Flower disorders

Different types of malformations were observed under high temperature during summer.

4.5.3.1. Vegetative malformation

The stamens of petals are converted into hand greenish mass protruding out of petals. It was observed in Arka Ivory, Emma and Noblesse

4.5.3.2. Unfurling of petals

The flowers failed to open for a long even the calyx get reflexed. It was observed in varieties Gold strike and Revival.

4.5.3.3. Bending of flower

The flower faces particular direction only. Bending of flower near the calyx and facing towards particular direction observed in cut flower variety Noblesse and loose flower variety Vernish.

4.5.5.3.4. Deformed petals

The flower was produced with less number of petals which are narrow in variety Peach Avalanche and Revival. Rudimentary petals were observed on Noblesse and Red varnish.

4.6. DIVERSITY ANALYSIS

The extent of diversity among the genotypes determines the success of any breeding programme. Selection of parents from diverse genotypes results in better improvement on the characters. Cluster analysis was carried out by using D^2 statistics and dendrogram constructed by Agglomerative method (Day and Eldelsbrunner, 1984).

4.6.1. Cut flower

4.6.1.a. Cluster analysis based on Quantitative Characters

The varieties included in each cluster of dendrogram based on quantitative characters are furnished in Table 24. The cut flower varieties Arka Ivory, Noblesse and Taj Mahal having similarity in days taken for appearance to opening of flower buds, number of sprouts per plant, stalk length, neck length and yield of marketable flowers formed cluster I. The varieties Arka Swadesh and Revival were similar with respect to diameter of flower bud, fresh weight of flower, number of flowers per plant, number of petals per flower and length of flower shoot and included in Cluster II. Cluster IV consisted of two varieties *viz.* Arka Pride and Gold Strike. These two varieties were similar with respect to length and diameter of flower bud and vase life.

Table 24. Clustering based on quantitative characters in cut flower varieties

Cluster No.	No. of cut flower varieties	Cut flower variety	Similar characters shared between cut flower varieties
Cluster I	3	Arka Ivory, Noblesse, Taj Mahal	Days taken for emergence to opening of flower buds, Number of flowers per sprout, stalk length, neck length, yield of marketable flowers
Cluster II	2	Arka Swaesh, Revival	Diameter of flower bud, fresh weight of flower, Number of flowers per plant, Number of petals per flower, length of flower shoot
Cluster III	1	Emma	
Cluster IV	2	Arka Pride, Gold Strike	Length of flower bud, diameter of flower bud, vase life
Cluster V	1	Peach Avalanche	
Cluster VI	1	Corvette	

Table 25. Clustering based on qualitative characters in cut flower varieties

Cluster No.	No. of cut flower varieties	Cut flower variety	Similar characters shared between cut flower varieties
Cluster I	3	Arka Ivory, Arka Pride, Noblesse	Semi upright growth habit, many number of prickles, pink blend in colour, medium fragrance
Cluster II	4	Arka Swadesh, Taj Mahal, Peach Avalanche	Medium serration of leaf margin, weak fragrance
Cluster III	1	Emma	
Cluster IV	3	Gold Strike, Revival, Corvette	Dense serration of leaf margin

The remaining clusters consisted of only one member and are distinct from other clusters.

4.6.1.b. Cluster analysis based on qualitative characters

The cut flower varieties were grouped into 4 clusters at 34 per cent similarity coefficient. Varieties included in each cluster are presented in Table 25. The varieties Arka Ivory, Arka Pride and Noblesse were similar with respect to characters *viz.* semi up right growth habit, many numbers of prickles, pink blend colour and medium fragrance. Cluster II had three varieties *viz.* ArkaSwadesh, Taj Mahal, and Peach Avalanche sharing similar characteristics *viz.* weak fragrance and medium serrations of leaf margin. The varieties Gold Strike, Revival and Corvette constitutedcluster IV with similar characters *viz.* dense serration of leaf margin and medium prickles on shoot. Variety Emma formed distinct Cluster III.

4.6.2. Loose flower

4.6.2. a. Cluster analysis based on quantitative characters

The loose flower varieties were highly variable with respect to qualitative floral characters and clustering could be done only at 6 per cent similarity coefficient and the varieties were grouped in to five clusters (Table 26).

Cluster I and II consisted of only one variety each. Cluster III consisted of two varieties *viz.* Sherba Gold and Red Varnish and Cluster IV with Mirabel and Charisma. They had similarity with respect to characters like duration of flowering, flower persistence and number of flowers per plant. Cluster V consisted of varieties Vernish and Jadiov having similarities in duration of flowering, days taken from initiation to opening of flower buds, fresh weight of flower, flower persistence, length of flower bud and diameter of flower bud. The varieties Spray Yellow and Spray

Table 26. Clustering based on quantitative characters in loose flower varieties

Cluster No.	No. of loose flower varieties	Loose flower variety	Similar characters shared between loose flower varieties
Cluster I	1	Arka Parimala	
Cluster II	1	Star Light	
Cluster III	2	Sherba Gold, Red Varnish	Duration of flowering, flower persistence, Number of flowers per plant
Cluster IV	2	Mirabel, Charisma	Duration of flowering, flower persistence, Number of flowers per plant
Cluster V	2	Vernish, Jadiov	Duration of flowering, days taken for initiation to emergence of flower buds, fresh weight of flower, Flower persistence, Diameter of flower bud, Length of flower bud
Cluster VI	2	Spray Orange, Spray Yellow	Duration of flowering, days taken for emergence to opening of flower buds, diameter of flower bud, length of flower bud, Number of flowers per sprout, Number of flowers per plant, Number of petals per flower, flower diameter at fully opened stage

Table 27. Clustering based on qualitative characters in loose flower varieties

Cluster No.	No. of loose flower varieties	Loose flower varieties	Similar characters shared between loose flower varieties
Cluster I	4	Arka Parimala, Vernish, Star Light, Red Varnish	Red blend of flower colour
Cluster II	1	Sherba Gold	
Cluster III	4	Mirabel, Charisma, Spray Orange and Spray Yellow	Dense leaf margin
Cluster IV	1	Jadiov	

Orange formed cluster VI as they shared common features such as duration of flowering, days taken from emergence to opening of flower buds, diameter of flower bud, length of flower bud, number of flowers per sprout, number of flowers per plant, number of petals per flower and flower diameter at fully opened stage.

4.6.2.b Cluster analysis based on qualitative characters

The loose flower varieties were grouped into 4 clusters at 36 per cent similarity coefficient. The varieties ArkaParimala, Vernish, Star Light and Red Varnish were grouped in to cluster II. They were similar with respect to characters *viz*. red colour blend. Cluster III had two varieties Mirabel and Charisma, Spray Orange and Spray Yellow sharing similar characteristics of dense leaf margin. Cluster II and IV constituted by Sherba Gold and Jadiov respectively with distinct qualitative characters (Table 27).

4. 7. VARIABILITY, HERITABILITY AND GENETIC ADVANCE

The genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability, genetic advance (GA) and genetic advance as per cent of mean (GAM) for the different floral traits of cut flower and loose flower varieties were studied and given in Table 28 and 29 respectively.

4.7.1. Cut flower

4.7.1.1. Days taken for appearance to opening of flower buds

This character recorded low GCV and PCV of 7.47 per cent and 9.48 per cent respectively. A high heritability of 62.06 was reported in this character along with low genetic advance (1.61) and moderate genetic advance as percent of mean (12.12).

4.7.1.2. Length of flower bud

Table 28. Genetic parameters for floral traits for cut flower

SI. No.	Character	GCV (%)	PCV (%)	H^2 (%)	GA	GAM (%)
1	Days taken for emergence to opening of flower buds	7.47	9.48	62.06	1.61	12.12
2	Length of flower bud	5.51	10.97	25.19	0.13	5.69
3	Diameter of flower bud	8.61	12.49	47.57	0.13	12.24
4	Number of flowers/sprout	24.11	32.30	55.70	2.70	37.06
5	Number of flowers /plant	18.69	28.30	43.59	2.25	25.42
6	Number of petals per flower	40.08	43.56	84.63	23.97	75.95
7	Flower diameter at fully opened stage	3.14	10.02	9.79	0.12	2.02
8	Flower persistence	7.44	18.45	16.27	0.53	6.18
9	Duration of flowering	1.47	10.37	2.00	0.83	0.43
10	Length of flower shoot	8.66	17.86	23.50	1.72	8.65
11	Thickness of flower shoot	7.94	15.88	25.00	0.02	8.18
12	Neck length	10.63	13.19	65.01	1.02	17.66
13	Neck girth	3.47	9.18	14.29	0.04	2.70
14	Stalk length	6.68	13.78	23.50	1.72	6.67
15	Stalk girth of the flower	4.04	12.42	10.59	0.06	2.71
16	Yield of marketable flowers	20.74	24.04	74.26	2.24	36.82
17	Fresh weight of the flower	21.19	23.61	80.56	2.20	39.18
18	Vase life	15.70	18.82	69.53	1.02	26.96

Table 29.Genetic parameters for floral traits for loose flower

SI. NO.	Character	GCV (%)	PCV (%)	H^2 (%)	GA	GAM (%)
1	Days taken for emergence to opening of flower buds	6.73	9.90	46.26	1.35	9.43
2	Length of flower bud	14.57	16.02	82.73	0.52	27.31
3	Diameter of flower bud	12.62	17.49	47.57	0.16	15.21
4	Number of flowers/sprout	42.25	52.45	64.89	8.00	70.11
5	Number of flowers /plant	26.93	34.43	61.19	7.25	43.40
6	Number of petals per flower	55.42	55.58	99.43	50.12	113.84
7	Flower diameter at fully opened stage	25.89	28.71	81.32	1.94	48.10
8	Flower persistence	11.83	35.89	10.86	0.70	8.03
9	Duration of flowering	3.78	8.12	21.59	6.98	3.61
10	Yield of marketable flowers	56.25	59.99	87.93	25.02	108.67
11	Fresh weight of the flower	61.69	93.84	43.22	1.67	83.55
12	Weight of petals /flower	83.81	120.33	48.50	1.61	120.23

Low GCV of 5.51 and moderate PCV of 10.97 were recorded in this character. Heritability (25.19) was low in this parameter with a low genetic advance (0.13) and low genetic advance as percent of mean (5.69).

4.7.1.3. Diameter of flower bud

Low GCV and medium PCV (8.61 and 12.49 respectively) were observed for this character along with moderate heritability (47.57), low GA (0.13) and moderate GAM (12.24).

4.7.1.4. Number of flowers per sprout

High GCV and PCV (24.11 and 32.30) were observed in this character with a moderate heritability of 55.70, low genetic gain (2.70) and high GAM (37.06).

4.7.1.5. Number of flowers per plant

Moderate GCV (18.69) and high PCV (28.30) were recorded for this character. The heritability observed in the character was moderate (43.59) coupled with low genetic gain (2.25) and high GAM (25.52).

4.7.1.6. Number of petals per flower

High GCV and PCV of 40.08 and 43.56 were recorded in this trait. This character recorded high heritability of 84.63 with high genetic gain (23.97) and high GAM (75.95).

4.7.1.7. Diameter of flower at fully opened stage

Low GCV and moderate PCV (3.14 and 10.02 respectively) were recorded for this trait. Low heritability (9.79) coupled with low genetic gain (0.12) and GAM (2.02) were observed for this trait.

4.8.1.8. Flower persistence

Low GCV and moderate PCV of 7.44 and 18.45 respectively were observed in this character. This character exhibited low heritability, low genetic gain and GAM (16.27, 0.53, and 6.18 respectively).

4.7.1.9. Duration of flowering

Low GCV (1.47) and moderate PCV (10.37) were recorded in this character. Low heritability (2.00) coupled with low genetic gain (0.83) and GAM (0.83) were exhibited by this character.

4.7.1.10. Length of flower shoot

Low GCV and moderate PCV of 8.66 and 17.86 respectively were recorded in this character. Low heritability (23.50) along with low genetic gain (1.72) and GAM (8.65) were observed in this character.

4.7.1.11. Thickness of flower shoot

Low GCV (7.94) and PCV (15.88) were exhibited by this character. The heritability reported was low (25.00) along with low genetic gain (0.02) and GAM (8.18).

4.7.1.12. Neck length

Moderate GCV and PCV (10.63 and 13.19 respectively) were observed in this character. This character exhibited high heritability of 65.01 and low genetic gain of 1.02 and moderate GAM of 17.66.

4.7.1.13. Neck girth

Low GCV and PCV of 3.47 and 9.18 were recorded in this character. Other genetic parameters like heritability, genetic gain and GAM were also low in this character (14.29, 0.04, and 2.70 respectively)

4.7.1.14. Length of stalk

Low GCV and moderate PCV (6.68 and 13.78 respectively) were recorded in this character. The heritability, genetic gain and GAM were also low (23.50, 1.72 and 6.67 respectively).

4.7.1.15. Stalk girth of flower

Low GCV (4.04) and moderate PCV (12.42) were recorded by this trait and the heritability (10.59), genetic advance (0.06) and GAM (2.71) were low with respect to this character.

4.7.1.16. Yield of marketable flowers

High GCV and PCV (20.74 and 24.04) were recorded for this parameter. High heritability (74.26), moderate genetic advance (2.24) and high GAM (36.82) were observed with regard to this character.

4.7.1.17. Fresh weight of the flower

High GCV and PCV of 21.19 and 23.61respectively were observed in this trait. High heritability of 80.56 along with low genetic advance of 2.20 and high GAM of 39.18 were exhibited by this trait.

4.7.1.18. Vase life

Moderate GCV and PCV (15.7 and 18.82 respectively) were recorded in this character. Heritability was high (69.53) coupled with low genetic advance of 1.02 and high GAM of 26.96 with respect to this character.

4.7.2. Loose flowers

4.7.2.1. Days taken from emergence to opening of flower buds

Low GCV and PCV of 6.73 and 9.90 respectively were observed in this character. Heritability was medium with low genetic advance and low GAM (46.26, 1.35, and 9.43).

4.7.2.2. Length of flower bud

This character showed moderate GCV and PCV of 14.57 and 16.02 respectively. High heritability of 82.73 and low genetic gain of 0.52 and high GAM of 27.31 were noticed in this trait.

4.7.2.3. Diameter of flower bud

Moderate GCV and PCV of 12.62 and 17.49 respectively were observed in this trait. Moderate heritability (47.57), low genetic gain (0.16) and low GAM (15.21) were exhibited by this character.

4.7.2.4. Number of flowers per sprout

High GCV and PCV of 42.25 and 52.45 were respectively exhibited by this trait. Heritability was high (64.89) with low genetic gain (8.00) and high GAM (70.11) for this character.

4.7.2.5. Number of flowers per plant

High GCV and PCV (26.93 and34.43 respectively) were observed in this trait. This character also exhibited high heritability of 61.19, low genetic gain (7.25) and high GAM (43.40).

4.7.2.6. Number of petals per flower

High GCV and PCV (55.42 and 55.58) were observed in this character. High heritability (99.43) coupled with high genetic advance (50.12) and high GAM of (113.84) were recorded in this character.

4.7.2.7. Flower diameter at fully opened stage

High GCV and PCV (25.89and 35.89 respectively) noticed in this character. High heritability of 81.32, low genetic gain of 1.94 and high GAM of 48.10 exhibited by this character.

4.7.2.8. Flower persistence

Moderate GCV and high PCV (11.83 and 35.89 respectively) were noticed in this character. This character recorded low heritability (10.86), low genetic gain (0.70) and low GAM (8.03).

4.7.2.9. Duration of flowering

Low GCV and PCV (3.78 and8.12) were noticed in this character. This character exhibited low heritability (21.59) along with low genetic gain (6.98) and high GAM (3.61).

4.7.2.10. Yield of marketable flowers

High GCV and PCV (56.25and 59.99 respectively) were reported in this trait. This character recorded high heritability, genetic gain and GAM (87.93, 25.02, and 108.67 respectively).

4.7.2.11. Fresh weight of flower

High GCV (61.69) and PCV (93.84) were noticed in this trait. This trait reported moderate heritability and genetic gain (43.22, 1.67) along with high GAM (83.55).

4.7.2.12. Weight of petals per flower

This character recorded high GCV and PCV (83.81and 120.33 respectively).This character exhibited moderate heritability (48.50) and low genetic gain (1.61) and high GAM (120.23).

4.8. CORRELATION AND PATH ANALYSIS

4.8.1. Cut flower

4.8.1.1. Correlation coefficient studies with respect to number of marketable flowers per plant

The correlation study helps in selection through other characters affecting the desirable character. The genotypic and phenotypic correlations are represented in Table 30 and Table 31 respectively. Phenotypic correlation includes both genetic and environmental effects while genotypic correlation provides information about correlation due to genetic effects only.

The characters number of flowers per sprout (0.464, 0.456), number of flowers per plant (0.970, 0.795), number of petals per flower (0.436, 0.412), fresh weight of the flower (0.803, 0.694) and number of sprouts per plant (0.557, 0.432) exhibited significant and positive correlation on number of marketable flowers per plant at genotypic and phenotypic levels whereas number of branches per plant, number of leaves per branch and plant height had significant correlation at genotypic level only (0.452,0.462, 0.580 respectively). The stalk length of the flower exhibited a significant and negative correlation (-0.514) at genotypic level.

4.8.1.2. Direct effects on number of marketable flowers per plant

The direct and indirect effect of different characters on flower yield per plant in rose is furnished in Table 32. High direct effect on number of marketable flowers per plant was exhibited by number of flowers per plant (0.592), plant height (0.384)

Table 30. Genotypic correlation matrix among number of marketable flowers in cut flower varieties

Characters	Number of flowers per sprout	Number of flowers per plant	Number of petals per flower	Stalk length	Fresh weight of the flower	Plant height	Number of sprouts per plant	Number of branches per plant	Number of leaves per plant
Number of flowers per sprout									
Number of flowers per plant	0.612**								
Number of petals per flower	0.150^{NS}	0.146^{NS}							
Stalk length	-0.432*	-0.667**	-0.035^{NS}						
Fresh weight of the flower	0.445*	0.640**	0.696**	0.106^{NS}					
Plant height	0.447*	-0.148^{NS}	0.584**	0.536**	0.364*				
Number of sprouts per plant	-0.378*	0.519**	-0.032^{NS}	-0.272^{NS}	0.123^{NS}	-0.501**			
Number of branches per plant	0.523**	0.730**	-0.124^{NS}	-0.230^{NS}	0.261^{NS}	-0.251^{NS}	0.243^{NS}		
Number of leaves per plant	0.343^{NS}	0.230^{NS}	0.075^{NS}	0.394*	0.681**	0.645**	-0.030^{NS}	-0.377*	
Number of marketable flowers	0.464**	0.970**	0.436*	-0.514**	0.803**	0.580**	0.557**	0.452*	0.462*

Table 31. Phenotypic correlation matrix among number of marketable flowers in cut flower varieties

Characters	Number of flowers per sprout	Number of flowers per plant	Number of petals per flower	Stalk length	Fresh weight of the flower	Plant height	Number of sprouts per plant	Number of branches per plant	Number of leaves per plant
Number of flowers per sprout									
Number of flowers per plant	0.592**								
Number of petals per flower	0.162^{NS}	0.144^{NS}							
Stalk length	-0.266^{NS}	-0.262^{NS}	-0.074^{NS}						
Fresh weight of the flower	0.384*	0.448*	0.568**	0.072^{NS}					
Plant height	0.345^{NS}	-0.045^{NS}	0.359^{NS}	0.383*	0.382*				
Number of sprouts per plant	-0.328^{NS}	0.352^{NS}	-0.068^{NS}	-0.021^{NS}	0.078^{NS}	-0.392*			
Number of branches per plant	0.424*	0.646**	-0.052^{NS}	-0.122^{NS}	0.100^{NS}	-0.091^{NS}	0.109^{NS}		
Number of leaves per plant	0.248^{NS}	0.186^{NS}	0.048^{NS}	0.050^{NS}	0.272^{NS}	0.255**	0.206^{NS}	-0.206^{NS}	
Number of marketable flowers	0.456*	0.795**	0.412*	-0.188^{NS}	0.694**	0.171^{NS}	0.432*	0.273^{NS}	0.298^{NS}

Table 32. Path analysis with direct and indirect effect on number of marketable flowers per plant in cut flower

Characters	Number of flowers per sprout	Number of flowers per plant	Number of petals per flower	Stalk length	Fresh weight of the flower	Plant height	Number of sprouts per plant	Number of branches per plant	Number of leaves per plant
Number of flowers per sprout	**0.218**	0.351	0.024	-0.001	0.115	-0.013	-0.102	-0.117	-0.017
Number of flowers per plant	0.129	**0.592**	0.021	-0.001	0.134	0.002	0.110	-0.178	-0.013
Number of petals per flower	0.035	0.085	**0.146**	0.000	0.169	-0.014	-0.021	0.014	-0.003
Stalk length	-0.058	-0.155	-0.011	**0.006**	0.022	-0.015	-0.007	0.034	-0.003
Fresh weight of the flower	0.084	0.266	0.083	0.000	**0.298**	-0.015	0.024	-0.028	-0.019
Plant height	0.075	-0.027	0.052	0.002	0.114	**0.384**	-0.122	0.025	-0.011
Number of sprouts per plant	-0.072	0.208	-0.010	0.000	0.023	0.015	**0.311**	-0.030	-0.014
Number of branches per plant	0.092	0.383	-0.008	-0.001	0.030	0.003	0.034	**0.275**	0.014
Number of leaves per plant	0.054	0.110	0.007	0.000	0.081	-0.006	0.064	0.057	**-0.070**

Residual effect = 0.127

129

and number of sprouts per plant (0.311) whereas moderate direct effect was exhibited by number of flowers per sprout (0.218), fresh weight of the flower (0.298) and number of branches per plant (0.275). Low positive direct effect (0.146) was exhibited by number of petals per flower. The direct effects of other vegetative as well as floral characters were negligible.

4.8.1.3. Indirect effects on number of marketable flowers per plant

4.8.1.3.1. Number of flowers per sprout

Number of flowers per sprout exhibited high positive indirect effect (0.351) on number of marketable flowers *via* high positive direct effect of number of flowers per plant (0.592) and low indirect effect (0.115) through the moderate positive direct effect of fresh weight (0.298) of the flower.

4.8.1.3.2. Number of flowers per plant

Number of flowers per plant had low positive indirect effect on number of marketable flowers (0.129, 0.134, 0.110) through the moderate positive direct effects of number of flowers per sprout, fresh weight of the flower and high positive direct effect of number of sprouts per plant (0.218, 0.298, 0.311) respectively.

4.8.1.3.3. Number of petals per flower

Number of petals per flower had low positive indirect effect (0.169) on number of marketable flowers per plant through moderate positive direct effect of fresh weight (0.592) of the flower.

4.8.1.3.4. Stalk length of the flower

Stalk length of the flower had low negative indirect effect (-0.155) on number of marketable flowers per plant through the high positive direct effect (0.592) of number of flowers per plant.

4.8.1.3.5. Fresh weight

Fresh weight of the flower exhibited moderate positive indirect effect (0.266) on number of marketable flowers per plant through the high positive direct effect of number of flowers per plant (0.592).

4.8.1.3.6. Plant height

Plant height had a low positive indirect effect on number of marketable flowers per plant (0.114) through the moderate positive direct effect of fresh weight of the flower (0.298). Low negative indirect effect (-0.122) was exhibited through the high positive direct effect of number of sprouts per plant (0.311).

4.8.1.3.4.6. Number of sprouts per plant

Number of sprouts per plant had moderate positive indirect effect (0.208) on number of marketable flowers through the high positive direct effect of number of flowers per plant (0.592).

4.8.1.3.7. Number of branches per plant

Number of branches per plant had high positive indirect effect (0.383) on number of marketable flowers per plant through the high positive direct effect of number of flowers per plant (0.592).

4.8.1.3.8. Number of leaves per plant

Number of leaves per plant had low positive indirect effect (0.110) on number of marketable flowers per plant through the high positive direct effect of number of flowers per plant (0.592).

4.8.2. Loose flower

4.8.2.1. Correlation coefficient studies with respect to marketable yield

The genotypic and phenotypic correlations in loose flowers are furnished in Table 33 and Table 34 respectively. Among loose flower varieties, number of sprouts per plant (1.073,0.875), plant spread (1.049, 0.852), number of petals per flower (0.669, 0.655), number of branches per plant (0.984, 0.636), length of flower bud (0.804, 0.615), diameter of flower bud (1.045,0.905) and plant height (1.041, 0.838) were significantly and positively correlated to flower yield per plant at genotypic and phenotypic levels.

4.8.2.2. Direct effects on flower yield per plant

The direct and indirect effect of different characters on marketable yield per plant in loose flower rose is given in Table 35. Very high direct effect on marketable yield per plant was exhibited by diameter of flower bud (3.076), plant height (3.055), plant spread (2.813) number of branches per plant (1.141) and length of flower bud (1.131). Fresh weight of the flower had high positive direct effect (0.910) on marketable yield and moderate direct effect was exhibited by number of flowers per plant (0.251) and number of petals per flower (0.285). Low positive direct effect was expressed through number of sprouts (0.100).

4.8.2.3. Indirect effects on flower yield per plant

The direct and indirect effect of different characters on marketable yield per plant in loose flower rose is given in Table 35. Very high direct effect on marketable yield per plant was exhibited by diameter of flower bud (3.076), plant height (3.055), plant spread (2.813) number of branches per plant (1.141) and length of flower bud (1.131). Fresh weight of the flower had high positive direct effect (0.910) on marketable yield and moderate direct effect was exhibited by number of flowers per plant (0.251) and number of petals per flower (0.285). Low positive direct effect was expressed through number of sprouts (0.100).

4.8.2.3.1. Plant height

Table 33. Genotypic correlation matrix among flower yield contributing attributes in loose flower varieties

Characters	Plant height	No. of sprouts	Plant spread	No. of branches per plant	No .of flowers per plant	Length of flower bud	Diameter of flower bud	No. of petals per flower	Fresh weight of the flower
No. of sprouts	-1.003**								
No. of branches per plant	0.998**	-1.041**							
No .of flowers per plant	0.956**	-1.000**	0.818**						
Length of flower bud	-0.243NS	0.145NS	-0.384*	0.054NS					
Diameter of flower bud	0.746**	-0.750**	0.859**	0.408*	-0.319NS				
No. of petals per flower	-0.997**	1.022**	-1.028**	-0.981**	0.207NS	-0.744**			
No. of petals per flower	0.710**	-0.719**	0.723**	0.766**	-0.141NS	0.317NS	-0.700**		
Fresh weight of the flower	0.005NS	-0.097NS	0.188NS	-0.092NS	-0.876**	0.134NS	-0.073NS	0.403*	
Marketable yield per plant	1.041**	1.073**	1.049**	0.984**	0.156**	0.804**	1.045**	0.669**	0.104**

133

Table 34. Phenotypic correlation matrix among flower yield contributing attributes in loose flower varieties

Characters	Plant height	No. of sprouts	Plant spread	No. of branches per plant	No .of flowers per plant	Length of flower bud	Diameter of flower bud	No. of petals per flower	Fresh weight of the flower
Plant height									
No. of sprouts	-0.933**								
Plant spread	0.928**	-0.891**							
No. of branches per plant	0.690**	-0.619**	0.667**						
No .of flowers per plant	-0.171NS	0.160NS	-0.246NS	0.102NS					
Length of flower bud	0.672**	-0.710**	0.684**	0.200NS	-0.222NS				
Diameter of flower bud	-0.961**	0.962**	-0.919**	-0.650**	0.151NS	-0.737**			
No. of petals per flower	0.591**	-0.605**	0.606**	0.522**	-0.111NS	0.256NS	-0.627**		
Fresh weight of the flower	0.067NS	-0.025NS	0.156NS	0.198NS	-0.281NS	0.097NS	-0.098NS	0.318NS	
Marketable yield per plant	0.838**	0.875**	0.852**	0.636**	0.111**	0.615**	0.905**	0.655**	0.177**

Table 35. Path analysis with direct and indirect effect on per plant in loose flower varieties of rose

Characters	Plant height	No. of sprouts	Plant spread	No. of branches per plant	No .of flowers per plant	Length of flower bud	Diameter of flower bud	No. of petals per flower	Fresh weight of the flower
Plant height	**3.055**	0.101	-2.807	1.091	-0.061	0.844	-3.066	-0.202	0.004
No. of sprouts	-3.064	**0.100**	2.929	-1.140	0.036	-0.848	3.143	0.205	-0.088
Plant spread	3.048	0.105	**2.813**	0.933	-0.097	0.971	-3.163	-0.206	0.171
No. of branches per plant	2.921	0.100	-2.302	**1.141**	0.014	0.461	-3.018	-0.218	-0.083
No .of flowers per plant	-0.742	-0.015	1.080	0.062	**0.251**	-0.361	0.638	0.040	-0.798
Length of flower bud	2.278	0.075	-2.415	0.465	-0.080	**1.131**	-2.290	-0.090	0.122
Diameter of flower bud	-3.045	-0.103	2.892	-1.119	0.052	-0.842	**3.076**	0.199	-0.066
No. of petals per flower	2.168	0.072	-2.034	0.874	-0.036	0.358	-2.154	**0.285**	0.367
Fresh weight of the flower	0.014	0.010	-0.527	-0.105	-0.220	0.152	-0.223	-0.115	**0.910**

Residual effect = 0.018

4.8.2.3.1. Plant height

Plant height expressed very high positive indirect effect (1.091) on marketable yield per plant through very high positive direct effect of number of branches per plant (1.141). High positive indirect effect (0.844) was expressed by very high positive direct effect of length of flower bud (1.131). Low positive indirect effect (0.101) was exhibited by low positive direct effect number of sprouts per plant (0.100). Very high negative indirect effect (-3.066) was exhibited through direct positive effect of flower bud diameter (3.076). Moderate negative indirect effect (-0.202) was expressed through moderate positive direct effect of number of petals per flower (0.285).

4.8.2.3.2. Number of sprouts

Number of sprouts expressed very high positive indirect effect (3.143, 2.929) on marketable yield per plant through very high positive direct effect of diameter of flower bud and plant spread (3.076, 2.813 respectively). Very high negative indirect effect (-3.064,-1.140) was expressed through very high positive direct effect of plant height and number of branches per plant (3.055, 1.141) respectively. High negative indirect effect (-0.848) was expressed through very high positive direct effect of length of flower bud (1.131).

4.8.2.3.3. Plant spread

Plant spread exhibited very high positive indirect effect (3.048) on marketable yield per plant through very high direct effect (3.055) of plant height. High positive indirect effect (0.933, 0.971) was expressed through very high positive direct effect of number of branches per plant and length of flower bud (1.141, 1.131 respectively). Low positive indirect effect (0.171, 0.105) was expressed through high direct effect of fresh weight of flower and low positive direct effect of number of sprouts (0.910, 0.100) respectively. Very high negative indirect effect (-3.163) was expressed

through very high positive direct effect of diameter of flower bud (3.076). Moderate negative indirect effect (-0.206)was expressed through moderate positive direct effect of number of petals per flower (0.285).

4.8.2.3.4. Number of branches per plant

Number of branches per plant expressed very high positive indirect effect (2.921) on flower yield per plant through very high positive direct effect of plant height (3.055). High positive indirect effect (0.461) was expressed through very high positive direct effect of length of flower bud (1.31). Low positive indirect effect (0.100) was expressed through low positive direct effect of number of sprouts per plant (0.100). Very high negative indirect effect (-2.302, -3.018) was expressed through very high positive direct effect of plant spread (2.813) and very high positive direct effect of diameter of flower bud (3.076). Moderate negative indirect effect (-0.218) was noticed through moderate direct positive effect (0.285) of number of petals per flower.

4.8.2.3.5. Number of flowers per plant

Number of flowers per plant exhibited very high positive indirect effect (1.080) on marketable yield per plant through very high positive direct effect of plant spread (2.813). High positive indirect effect (0.638) was expressed through very high positive direct effect of diameter of flower bud (3.076). High negative indirect effect (-0.798,-0.742, -0.361) was expressed through high positive direct effect of fresh weight per flower, very high direct positive effect of plant height and flower bud length (0.910, 3.055, 1.131respectively).

4.8.2.3.6. Length of flower bud

Length of flower bud exhibited very high positive indirect effect (2.278) on flower yield per plant through very high direct effect of plant height (3.055). High positive indirect effect (0.465) was expressed through very high direct effect (1.141)

of number of branches per plant. Low positive indirect effect (0.122) was exhibited by high positive direct effect (0.910) of fresh weight of the flower. Very high negative indirect effect (-2.415, -2.290) was expressed through very high positive direct effect of plant spread (2.813) and diameter of flower bud (3.076).

4.8.2.3.7. Diameter of flower bud

Diameter of flower bud exhibited very high positive and indirect effect (2.892) through very high positive direct effect of plant spread (2.813). Low positive indirect effect (0.199) was expressed through moderate negative direct effect (0.285) of number of petals per flower. Very high negative indirect effect (-3.045, -1.119) was expressed through very high positive direct effect (3.055, 1.141) of plant height and number of branches respectively.

4.8.2.3.8. Number of petals per flower

Number of petals per flower exhibited very high positive indirect effect (2.168) on flower yield per plant through very high positive direct effect of plant height (3.055). High positive indirect effect (0.874, 0.367, and 0.358) was expressed through very high positive direct effect of number of branches (1.141), high positive direct effect of fresh weight of the flower (0.910) and very high positive direct effect of length of flower bud (1.131). Very high negative indirect effect (-2.034,-2.154) was expressed through very high positive direct effect of plant spread and diameter of flower bud (2.813, 3.076 respectively).

4.8.2.3.9. Fresh weight of the flower

Fresh weight of the flower exhibited low positive indirect effect (0.152) on marketable yield per plant through very high positive direct effect of length of flower bud (1.131). High negative indirect effect (-0.527) was expressed through very high positive direct effect of plant spread (2.813). Moderate negative indirect effect (-0.223, -0.220) was expressed through very high positive direct effect of flower bud

diameter (3.076) and moderate positive direct effect of number of petals per flower (0.251) respectively. Low negative indirect effect (-0.105, -0.115) was noticed through very high positive direct effect of number of branches per plant and moderate positive direct effect of number of petals per flower (1.141, 0.285).

Discussion

5. DISCUSSION

Rose is the long-time favourite flower of the world because of its astonishing beauty, fragrance, variety and long lasting blooming season. They vary in colours, fragrance, size, growth forms, foliage characteristics and adaptability to different climatic conditions. Rose ranks first among the top ten cut flowers of international market and widely used for aesthetic gratification in landscapes, as loose flowers, perfumery industry, floral crafts and its blooming potential in the field of food industry, pharmaceuticals, horticulture therapy are recently reported over the world.

A study was conducted at department of floriculture and landscaping, College of Horticulture, Vellanikkara during 2017-2018 to evaluate the performance of ten cut flower and ten loose flower varieties of rose under naturally ventilated poly house and the results are discussed here under.

5.1 VEGETATIVE CHARACTERS

5.1.1. Cut flowers

From the experiment, it could be observed that the varieties varied significantly with respect to vegetative characters. Regarding plant height, there was no significant variation among varieties up to six month of planting. After sixth month, the varieties Arka Pride, Taj Mahal and Emma were superior in terms of this parameter. The variety Gold Strike recorded lowest plant height among the ten varieties throughout the observation period. Even though there was no significant variation in plant spread among the varieties, superiority of the varieties Revival and Arka Swadesh could be observed in terms of this parameter at peak flowering stage (39.13 cm and 36.25 cm respectively).

The number of sprouts indicates the number of basal shoots produced and there was significant variation in this parameter throughout the growth period. The highest number of sprouts was observed in Arka Ivory. Regarding number of

branches per plant, there was no significant variation among the varieties during initial five months of planting and highest number of branches per plant was observed in variety Revival from sixth month onwards. No significant variation in number of leaves per branch could be observed during the period of observation. However more number of leaves was observed in Arka Ivory.

The variation in quantitative vegetative characters might be due to the genetic make up of the varieties resulted in differential response to the growing conditions. These results are in confirmity with the findings of Mohanty *et al.* (2011), Islam (2013), Singh *et al.* (2013), Ramzan *et al.* (2014), Atram *et al.* (2015), Gogoi *et al.* (2016) and Joshna and Sarkar (2018), and who had reported genetic factors and growing conditions as the main reasons for variation in morphological characters of the rose varieties.

Varieties varied significantly with respect to qualitative vegetative characters. Bush shape determines the planting density. Upright growth habit was exhibited by variety Corvette whereas semi upright growth habit was observed in varieties Arka Ivory, Arka Pride, Noblesse and Taj Mahal. Other varieties were having spreading growth habit. Amout of prickles varied from many in varieties Arka Ivory, Arka Pride, Arka Swadesh and Noblesse, medium in varieties Gold Strike, Revival, Taj Mahal and Corvette and few in Peach Avalanche. Variety Emma was without any prickles.

Cut flowers with long sturdy stem with attractive and healthy foliage are preferred in the market. Colour, leaf margin and leaf hairiness are important characters which decides the quality of foliage. In the present study, a variation in leaf colour ranging from light green, medium green, dark green and very dark green and varying degrees of serrations of leaf margin *viz.* fine, medium and dense were observed among the varieties. All the varieties were devoid of leaf hairiness. Nadeem *et al.* (2011) reported similar pattern in qualitative characters of foliage like leaf

colour and serration of leaf margin and a controversial result of presence of leaf hairiness in certain rose varieties.

5.1.2. Loose flowers

Significant variation was observed among loose flower varieties with respect to vegetative characters. Regarding plant height there was no significant variation among varieties up to fourth month. From fifth month onwards Arka Parimala was superior in terms of plant height. There was no significant variation in plant spread of loose flower varieties during the period of observation. Significant variation was observed with respect to number of sprouts and the varieties Charisma, Jadiov and Star Light produced highest number of sprouts. Highest number of branches was observed in varieties Arka Parimala, Charisma, Jadiov and Star Light. Regarding, number of leaves per branch, no significant variation could be observed among loose flower varieties. Similar variations in morphological characters of damask rose accessions were reported by Kudori *et al.* (2015) and Nasri et *al.* (2016).

Observations on qualitative vegetative parameters of loose flower varieties revealed that wide variation among the varieties. Bush shape varied from upright in variety Sherba Gold to strong spreading habit in variety Vernish. Amount of prickles was in the range from few to many. Leaf colour varied from light green in Vernish to very dark green in varieties Sherba Gold, Mirabel and Red Varnish. Fine serration to dense serration was observed in varieties. Similar variation in qualitative characters of *Rosa centifolia* accessions were reported by Akhtar *et al.* (2014).

5.2. FLORAL CHARACTERS

5.2.1. Cut flowers

Wide variation among cut flower varieties were observed with regard to floral characters. Days taken for emergence to opening of flower bud decides the earliness in flowering. In the present study, earliest flowering was observed in

varieties Emma, Arka Ivory and Gold Strike (11.73, 13.01 and 13.04 days respectively) and the variety Arka Pride took more number of days (14.73 days) to opening of flower buds. No significant variation among varieties could be observed with respect to flower persistence and duration of flowering.

Number of flowers per sprout, number of flowers per plant and yield of marketable flowers are important yield attributes and the varieties varied significantly with regard to these parameters (Fig.1). Varieties Revival and Arka Swadesh produced highest number of flowers per sprout (12.45 and 10.10 respectively) whereas highest number of flowers per plant and marketable yield were observed in varieties Arka Ivory (8.45), Taj Mahal (8.28) and Revival (7.23). All these variations are due to genetic makeup of the varieties. The varietal influence on yield parameters of rose was also reported by Dias and Patil, (2003), Paramagoudar *et al.* (2014), Ramzan *et al.* (2014) and Zuraw *et al.* (2015).

Among the cut roses, the floral characters *viz.* stalk length, stalk thickness, neck length, number of petals, length and diameter of flower bud and vase life are important quality aspects which determine the suitability for cut flower purpose. Varieties varied significantly with respect to quality parameters (Fig. 2). Length and diameter of flower bud were highest in varieties Arka Ivory and Taj Mahal. Number of petals per flower is an important quality parameter in rose (Fig. 3) and the variety Taj Mahal had highest number of petals per flower (79.54) followed by the varieties Noblesse (38.92), Peach Avalanche (33.68) and Emma (30.33). Among various selection criteria, neck length is an important and varieties with short neck length are preferred in the market. In the present investigation shortest neck length was observed in variety Gold Strike (4.31) followed by variety Taj Mahal (5.00).

Cut roses are mainly used in flower arrangements, bouquets and stage decorations which highly demands long and straight stem. Among the varieties

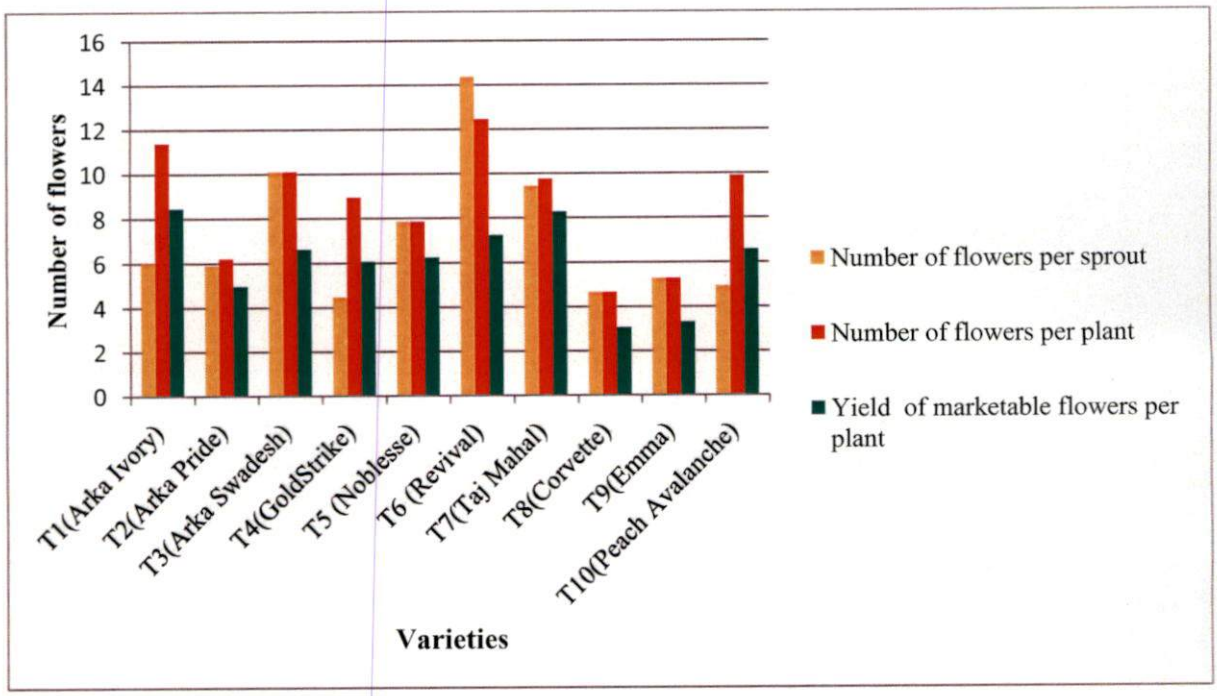


Figure 1. Yield characters of cut flower varieties

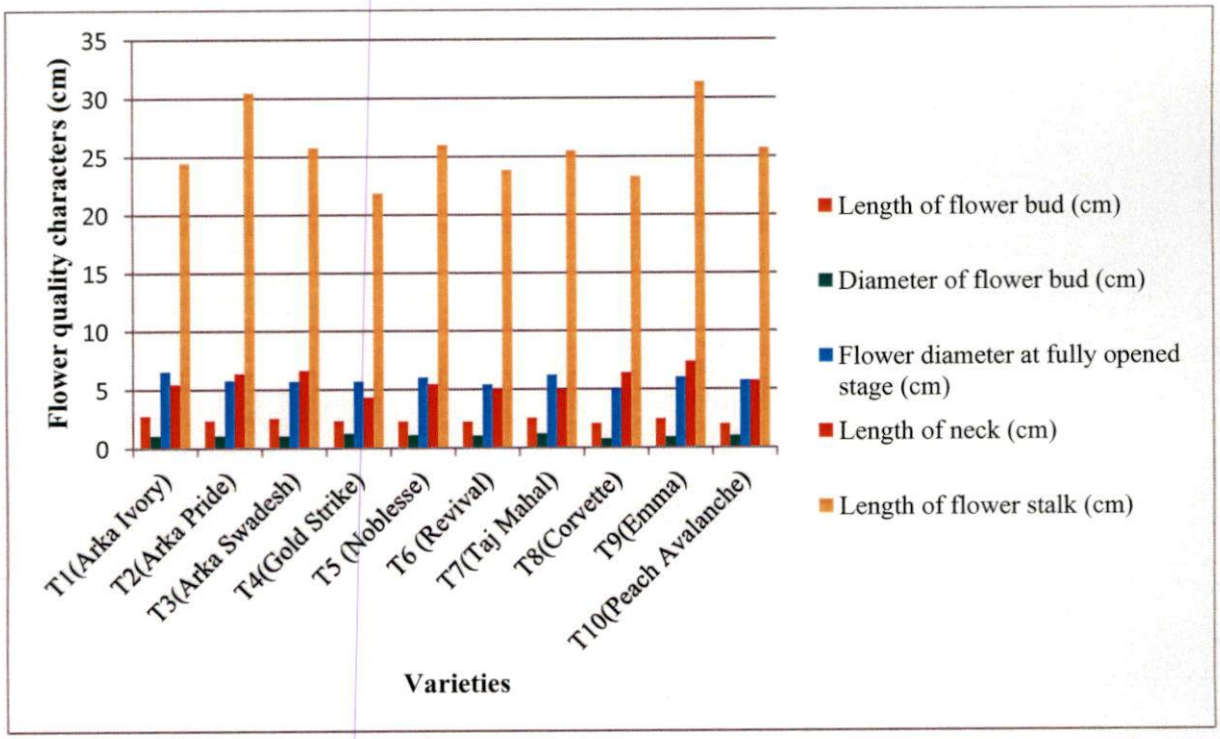


Figure 2. Flower quality characters of cut flower varieties

evaluated, the varieties Emma and Arka Pride were found to be the highest stalk length (31.35 cm and 30.48 cm respectively). No significant variation could be observed among the varieties with regard to other quality parameters like length and thickness of flower shoot and girth of flower stalk.

Number of thorns per 10 cm stalk length was rated as absent in variety Emma (Score-1) to many in variety Arka Ivory (Score-7). Fragrance was scored as per the rating scale 1-4 and medium fragrance was observed in varieties Arka Ivory, Arka Pride, Gold Strike and Noblesse and the rest of the varieties had weak fragrance. Regarding flower colour, variety Gold Strike was grouped under yellow blend, Corvette in orange blend, Arka Swadesh and Taj Mahal in red blend. All other varieties having different shades of pink were grouped under pink blend. The variation in qualitative floral characters and post harvest characters may be due to genetic makeup of the varieties.

The post harvest characters were varied significantly and are depicted in Figure 3. Highest fresh weight was observed in varieties Taj Mahal and Noblesse (8.08 g, 7.84 g). Physiological loss in weight was lowest in variety Arka Pride (1.68). Highest vase life was observed in varieties Revival, Noblesse and Taj Mahal (4.83, 4.75,4.75 days).These results are in confirmity with the findings reported by Atram *et al.* (2015), Shahrin *et al.* (2015) and Singh *et al.* (2017).

Based on quality characters like stalk length, length of flower bud and diameter of flower bud, number of petals per flower, vase life and number of marketable flowers, the overall performance of the varieties were scored and the variety Taj Mahal scored highest rank (1) followed by Noblesse (2). Shahrin *et al.* (2015) reported Taj Mahal as one of the best varieties based on overall performance.

Correlation studies help us to know the interaction between various characters and to identify components contributing to desirable a trait which makes the selection programme more effective. From the correlation studies, a negative

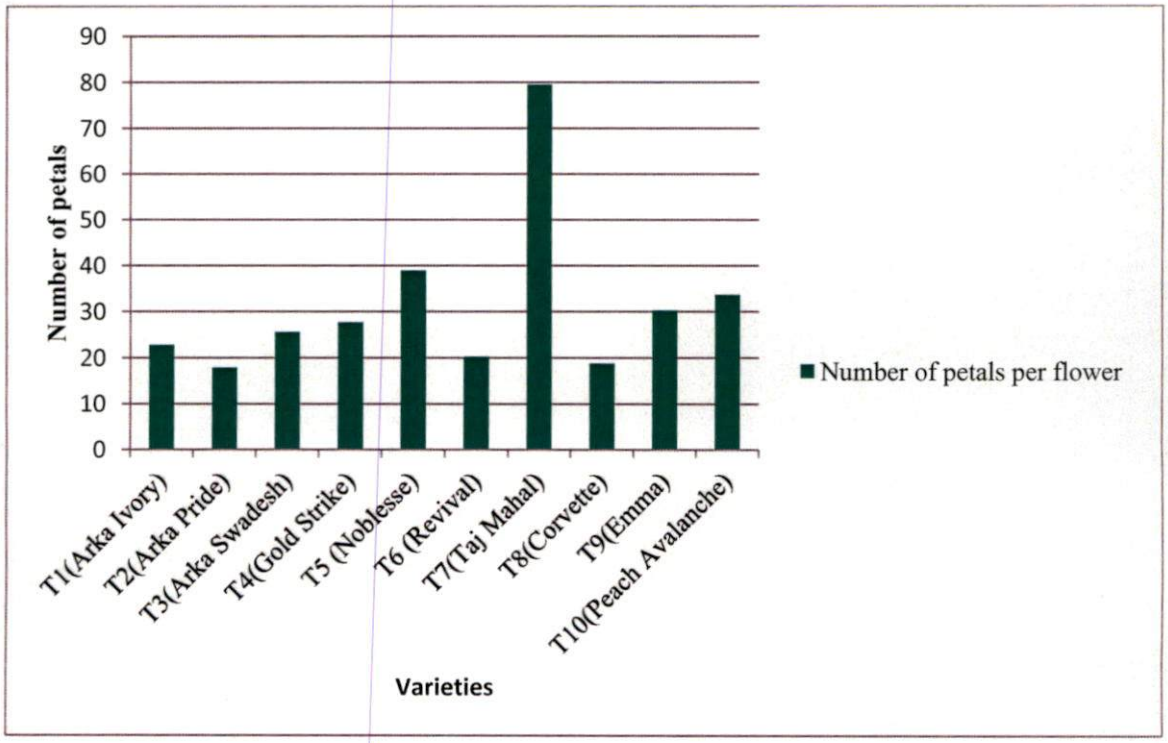


Figure 3. Number of petals in cut flower varieties

correlation could be observed between temperature and number of flowers per plant. It could be also observed that number of flowers is positively correlated with plant height, plant spread, number of sprouts and number of branches per plant. In the present study the varieties Revival and Peach Avalanche having highest number of branches produced highest number of flowers per plant.

5.2.2. Loose flowers

Loose flower varieties varied significantly with respect to floral characters. Earliest flowering was observed in varieties Charisma, Spray Yellow, Star Light, Spray Orange, Mirabel, Arka Parimala and Vernish. Knowledge of persistence of flower in the plant provides information about its field life. Among loose flowers, highest flower persistence was observed in varieties Sherba Gold, Charisma and Mirabel (12.0, 11.4 and 9.6 respectively). Yield potential of rose is influenced by parameters like number of flowers per sprout, number of flowers per plant and yield of marketable flowers (Figure 4). In the present study, highest number of sprouts was in variety Vernish (20.83) and Mirabel (20.55) while lowest was in Jadiov (5.4).

Regarding number of flowers per plant, highest number of flowers were observed in Red Varnish (22.38), Vernish (20.82), Charisma (20.6) and Mirabel (20.55). The lowest number of flowers was observed in Star Light (9.95) followed by Jadiov (10.81) and Sherba Gold (11.28). The variation in productivity may attributed to the genetic makeup of the varieties along with influence of environment. This is in accordance with the findings of Mantur *et al.* (2005), Atram *et al.* (2015) and Shivaprasad *et al*. (2016).

Regarding flower quality characters (Fig. 5), highest length of flower bud was observed in variety Arka Parimala. Varieties Sherba Gold, Arka Parimala, Vernish, Charisma and Star Light were superior in terms of diameter of flower bud (Figure 5). The flower diameter represents the size of the bloom. The variety Arka Parimala had the highest flower diameter (6 cm) along with longest bud. The lowest

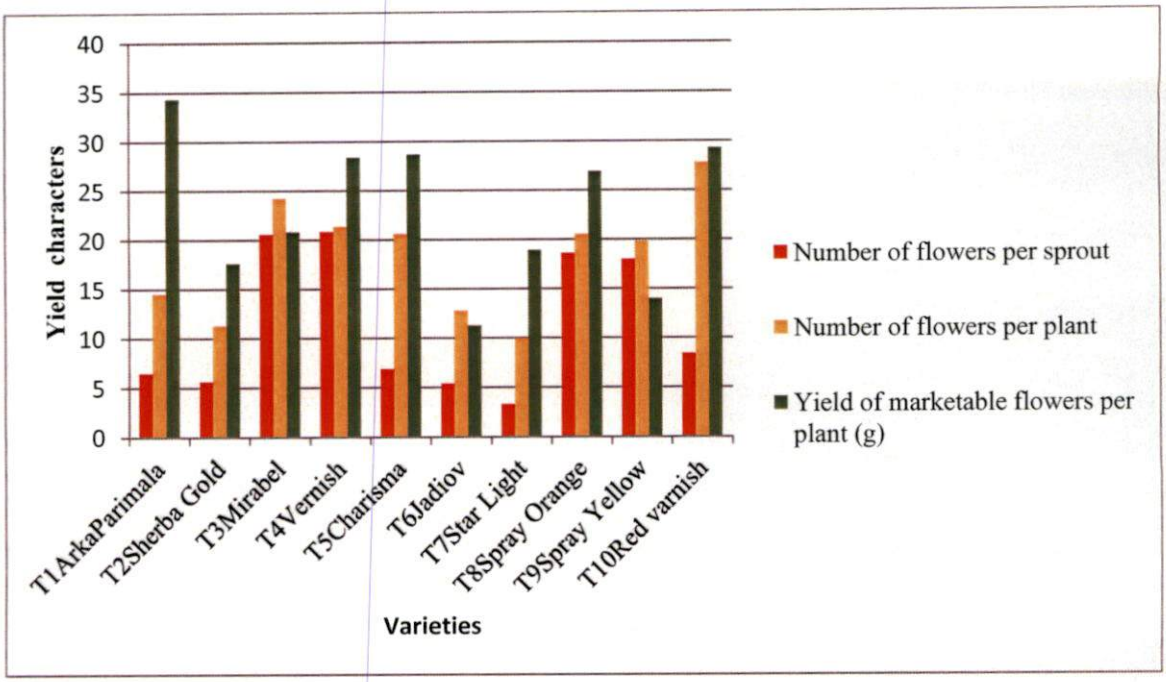


Figure 4. Yield characters of loose flower varieties

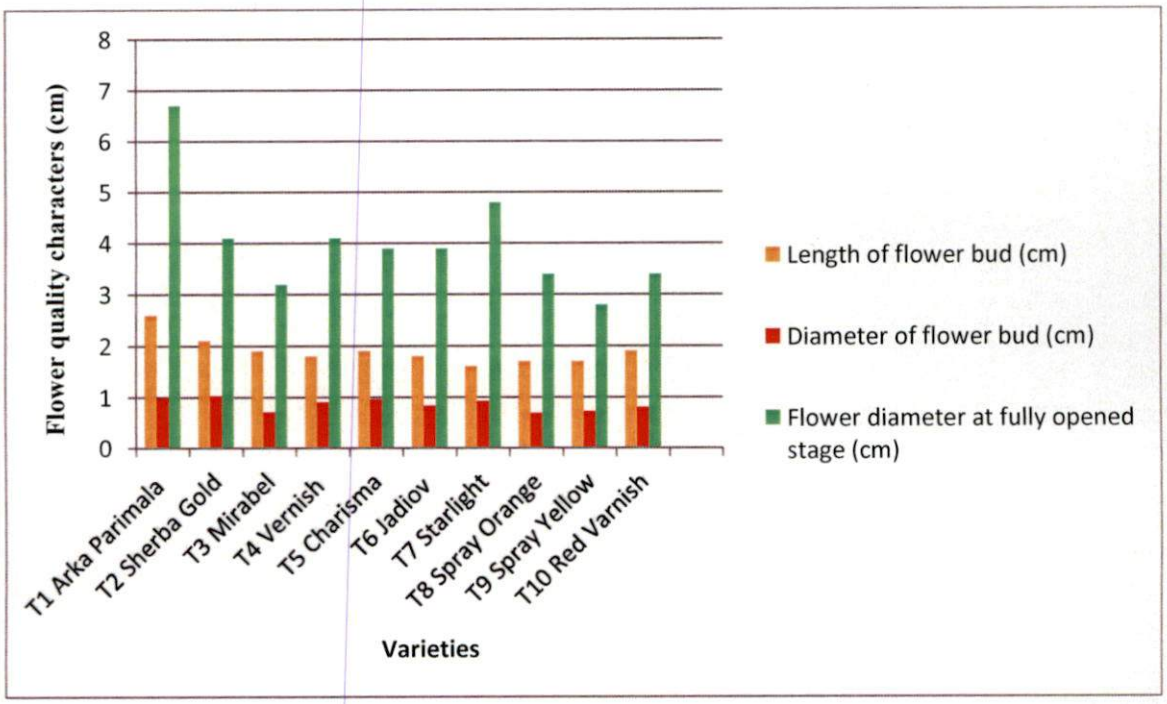


Figure 5. Flower quality characters of loose flower varieties

flower diameter was observed in variety Spray Yellow (2.3). The variation in flower size could be attributed to genetic make up of variety which is in confirmity with the findings Mohanty *et al.* (2011), Shivaprasad *et al.* (2016) and Singh *et al.* (2017).

Regarding post harvest characters, the fresh weight of the flower significantly varied among loose flower varieties and highest fresh weight was observed in the variety Star Light (3.16g) and Arka Parimala (3.14 g). The least fresh weight was recorded in variety Spray Yellow (1.13 g) followed by Spray Orange (1.49 g). The variation in flower weight is a varietal character due to its genetic makeup. These results are supported by the findings of Polara *et al.* (2004), Manjula (2005), Harshawardhan, (2009) and Joshna and Sarkar (2018).

The number of petals per flower is an important quality aspect as more number of petals provides a characteristic appearance to the flower (Fig. 6). Among loose flower varieties highest number of petals was observed in Star Light (102), followed by Sherba Gold (61.4), Charisma (57.4) and Mirabel (40.7). The lowest number of petals was observed in ArkaParimala (15.4). Weight of petals is an important criterion for loose flowers as they are sold as per weight basis. In the present study highest petal weight was observed in variety Star Light (2.78 g) followed by Arka Parimala (1.94 g), Sherba Gold (1.83 g) and Mirabel (1.21 g). The least petal weight was observed in variety Spray yellow (0.683 g). The variation in petal weight is a varietal feature resulted from the genetic make up of variety. Similar type of variation in weight of petals due to varietal influence was reported by Wasnik *et al.* (2014).

Colour is the most attractive attribute of a flower and the consumer preference for colour varies widely. Varieties Mirabel, Charisma, Jadiov and Spray Orange were orange blend in colour while Sherba Gold and Spray Yellow were in yellow blend. The varieties Arka Parimala, Vernish, Star Light and Red Varnish were

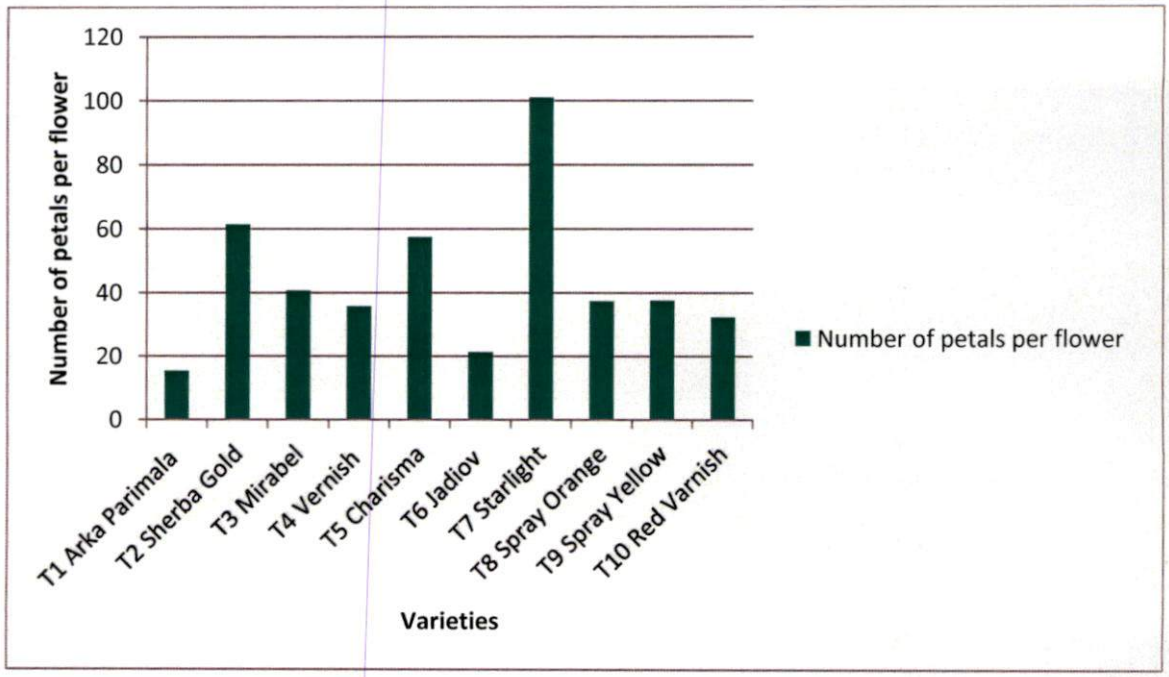


Figure 6. Number of petals in loose flower varieties

in red blend colour group. The variation among varieties for colour was similar to the reports of Nadeem *et al.* (2011) and Shahrin *et al.* (2015).

Clustered flowers are advantageous for loose flower varieties as they are small in size and have to be produced in large number. The varieties Arka Parimala, Sherba Gold, Jadiov and Star Light produced solitary flowers and these flowers were relatively larger in size. These results are supported by the findings of Nadeem *et al.* (2011). The loose flower varieties were devoid of any thorns in flower stalk. The variation in thorn density is a varietal characteristic due to the inherent genetic makeup and similar findings were reported by Dias and Patil (2003) and Harshawardhan (2009).

Fragrance is a very important quality parameter every one seeks in rose and the variation in fragrance was due to the variation in principal constituents contributing aroma. Among varieties evaluated, Arka Parimala recorded strong fragrance. Medium fragrance was observed in Star Light and Charisma while weak fragrance was observed in Sherba Gold, Mirabel, Spray Yellow and Spray Orange. The varieties Vernish, Jadiov and Red Varnish were devoid of fragrance. Fragrance in roses is controlled by gene action and the variation may be due to the level of constituents contributing aroma. This is in accordance with findings of Shahrin *et al.* (2015). Regarding shelf life there was no significant variation among varieties.

Based on quality attributes like fragrance, number of petals, flower diameter and yield of marketable flowers, the overall performance of the varieties were scored and the variety Star Light ranked first (1) followed by Arka Parimala (2), Sherba Gold (2) and Charisma (2).The loose flower varieties performed well under climatic conditions of Kerala even at the high temperature period during February. For getting marketable flowers even during summer season, it is essential to develop heat and thrips resistant varieties. The loose flower variety Arka Parimala can be recommended for oil extraction. The variety Star Light recorded highest number of

petals and flower size and hence it can be recommended for the purpose of garland making. The varieties Spray Orange, Spray Yellow and Sherba Gold can be recommended for dry flower making as the petals remain intact without falling for a long time in the plant. All the varieties were suitable for use in worshipping purpose and as pot plants.

5.3. Pest and diseases

The major disease found affecting the rose was black spot during September-January which is the most damaging disease of rose worldwide (Faheem*et al.,* 2016). It is caused by *Diplocarpon rosea* which is prevalent during the months of September to January. The disease spreads primarily through water and the irrigation water might have caused the spread of the disease in all varieties. The other leaf spots reported were caused by *Colletotrichum* during the months of October, Janauary and February; *Alternaria* during March and April; *Pestalotia* during October- November. The resistance of some varieties may be attributed to the genetic makeup of varieties. Crown gall, a bacterial disease was also found affecting the rose plant. The resistant varieties can be further screened for breeding of disease resistance.

Severe attack of thrips was observed during summer months. The flower quality was severely affected as they damage the petals and foliage. The petals became hardened and the flowers failed to open properly under severe conditions. The overall quality of the flower was lost due to infestation. The high temperature prevailed during the summer months might have caused severe infestation of thrips during these months. All the varieties were susceptible to the attack of thrips except Arka Ivory as it produced quality flowers under high temperature and under severe thrips attack. Similar results of attack of thrips in rose was reported by Duraimurugan and Jagadish, (2011). *Macrosiphum rosae*, *Thrips tabaci*, *Anomala orientalis*, *Aonidiell aaurantii*, *Achaea janata*, *Orgyiap osticus*, *Megachile anthracina*,

Odonototermes obesus were identified as the insect-pest complex reducing flower growth and quality of roses in Wayanad in Kerala (Smitha *et al.,* 2017).

The economic yield from the varieties during the period of observation (Figure 9 & 10) indicated that the highest marketable yield was obtained during the month of December. The pruning and fertilization along with a favourable temperature of 30 ^{0}C might have resulted in higher economic yield. As temperature increased from 30 ^{0}C during February, the flower production decreased and per cent of marketable flowers also decreased due to increased thrips incidence and increased number of malformed flowers.

5.4. GENETIC DIVERGENCE IN ROSE VARIETIES

The extent of diversity among genotype has to be analysed before designing a breeding programme. Selection will be effective if potent parents are selected from a diverse group. Genetic divergence was done by cluster analysis.

5.4.1. a. Cluster analysis based on quantitative characters in cut flower

The varieties sharing similar characteristics were clustered into same group (Fig. 7) The cut flower varieties does not form clusters even at 10 per cent similarity coefficient and at 3 per cent similarity coefficient form six clusters which indicate that there exists much variability among the ten cut flower varieties.

The cut flower varieties Arka Ivory, Noblesse and Taj Mahal were similar for the traits *viz.* days taken for appearance to opening of flower buds, number of sprouts per plant, stalk length, neck length and yield of marketable flowers. The Cluster II included varieties, Arka Swadesh and Revival sharing similarity in diameter of flower bud, fresh weight of flower, number of flowers per plant, number of petals per flower and length of flower shoot. Cluster III was constituted by Arka Pride and Gold Strike, sharing similarity in length and diameter of flower bud and vase life while selecting parents for a particular trait, selection should be done from different clusters as the members in the same cluster will be similar with respect to that particular trait.

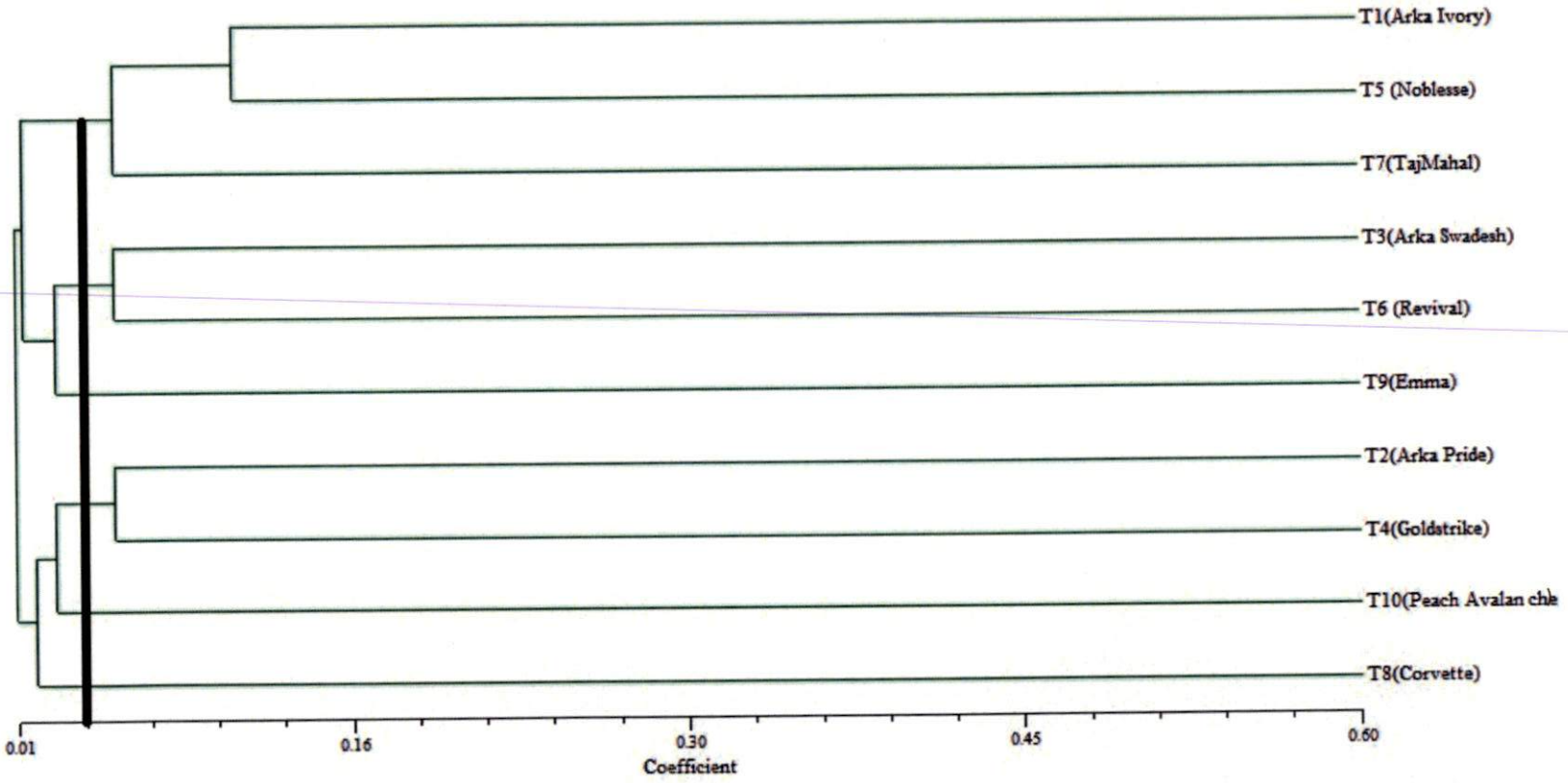


Figure 7. Dendrogram for quantitative characters for cut flower varieties

These results are in agreement with the findings of Tejaswini and Dhanajaya (2006) who reported cluster combinations among hundred and twenty seven rose varieties for hybridization programme to develop progenies with long stalk and keeping quality.

5.4.1. b. Cluster analysis based on qualitative characters in cut flower

The cut flower varieties were grouped into 3 clusters at 30 per cent similarity coefficient based on qualitative characters (Fig. 8). The varieties Arka Ivory, Arka Pride and Noblesse were grouped in cluster I. They were similar with respect to characters *viz.* semi up right growth habit, many numbers of prickles, pink blend in colour and medium fragrance. Cluster II had four varieties viz. Arka Swadesh, Taj Mahal, Emma and Peach Avalanche sharing similar characteristics *viz.* weak fragrance and medium serrations in leaf margin. The varieties Gold Strike, Revival and Corvette constituted cluster III with similar characters *viz.* dense serration in leaf margin and medium prickles on shoot. Chang *et al.* (2018) clustered 88 chrysanthemum varieties based on the type of petal present on each varieties.

5.4.2.a. Cluster analysis based on quantitative characters in loose flower

The loose flower varieties were clustered into six clusters (Fig. 9). Cluster I and II constituted by Arka Parimala and Star Light respectively and are distinct from other members. The varieties Sherba Gold and Mirabel formed cluster III and Charisma and Red varnish formed Cluster IV having similarity in flowering duration, flower persistence and no of flowers per plant. Cluster V was constituted by Vernish and Jadiov sharing similarity in duration of flowering, days taken for initiation to opening of flower buds, fresh weight of flower, flower persistence, length of flower bud and diameter of flower bud. The varieties Spray Orange and Spray Yellow having similar characteristics *viz.* duration of flowering, days taken for initiation to opening of flower buds, diameter of flower bud, length of flower bud, no of flowers per sprout, number of flowers per plant, no of petals per flower and flower diameter

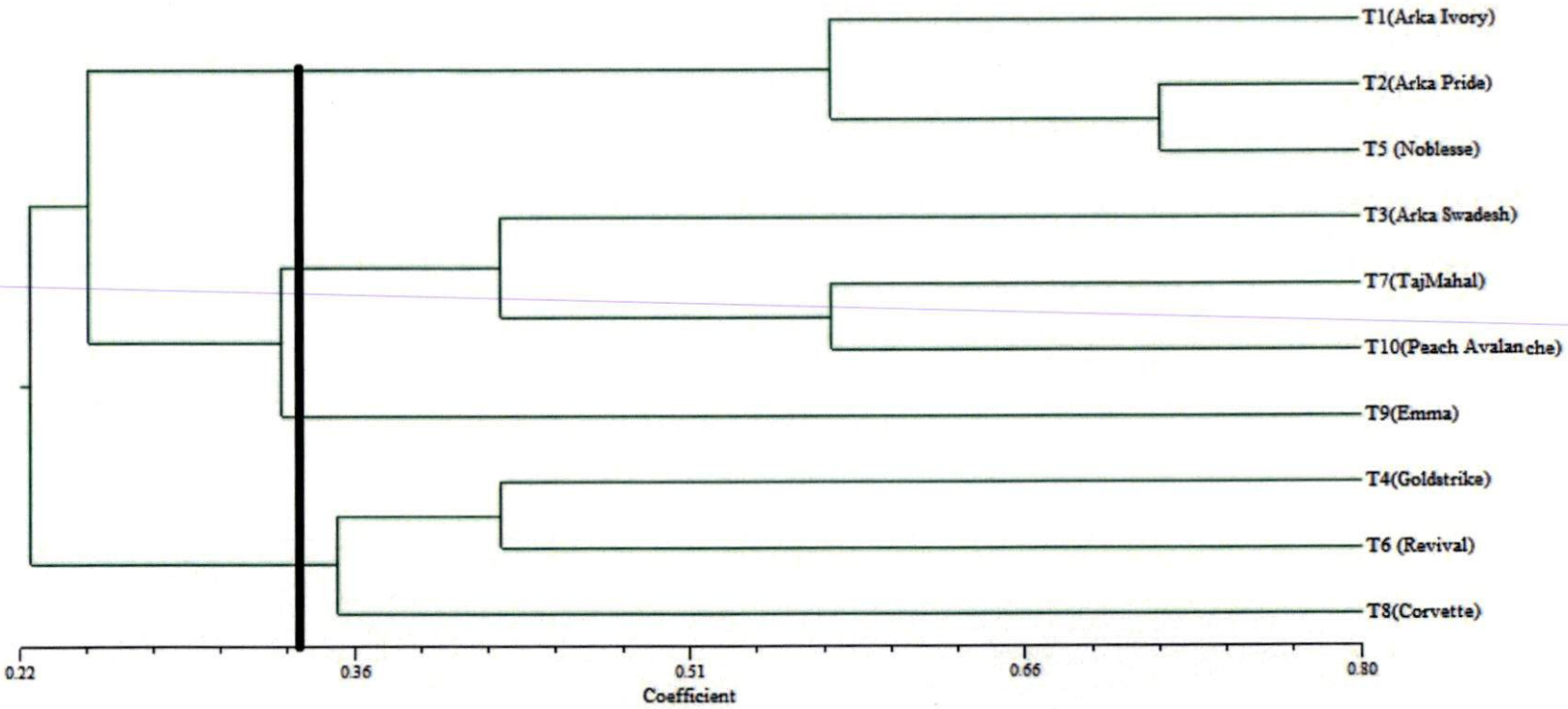


Figure 8. Dendrogram for qualitative characters for cut flower varieties

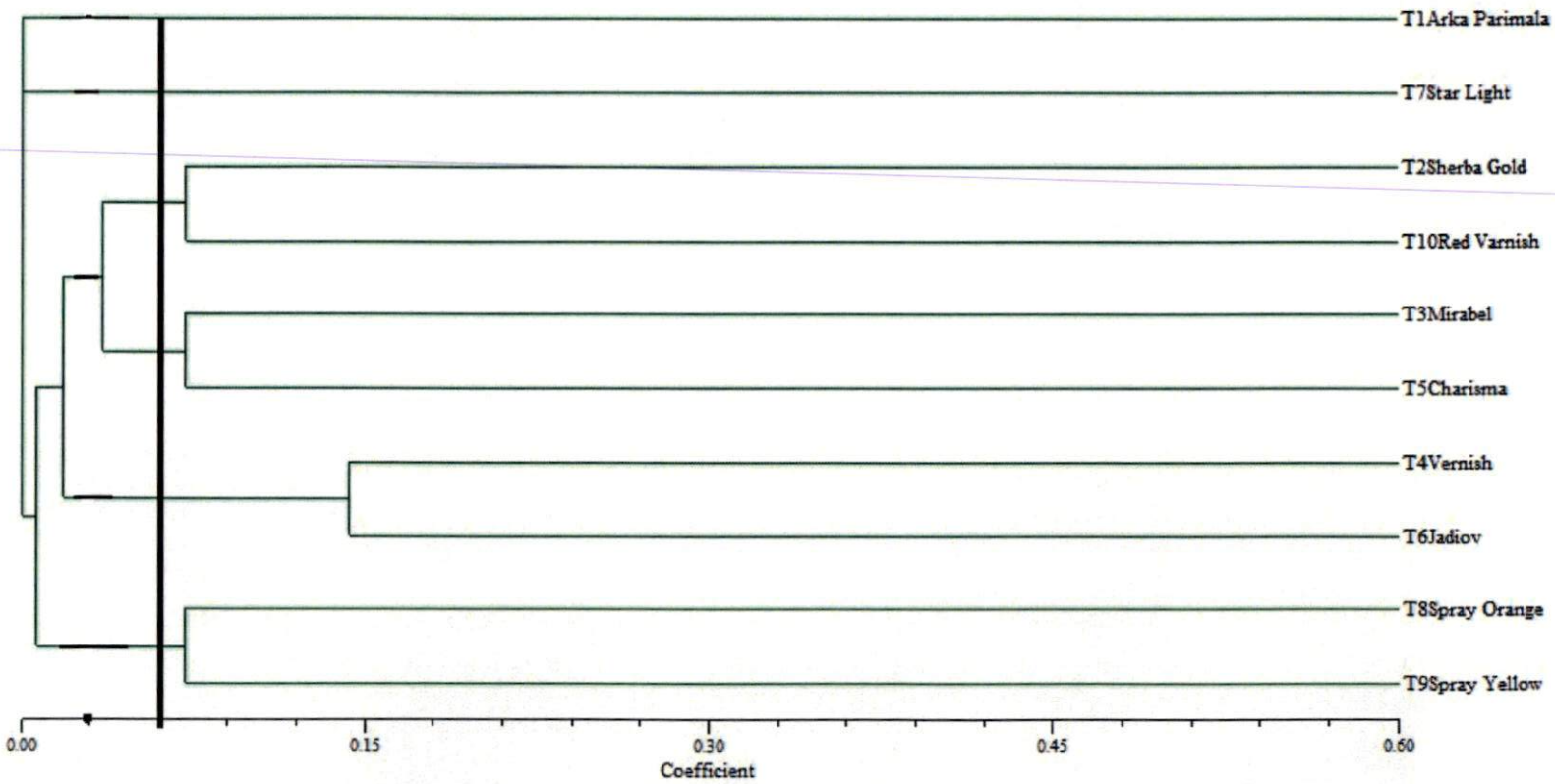


Figure 9. Dendrogram for quantitative characters of loose flower varieties

at fully opened stage formed cluster VI which indicated that improvement in any of the given characters parents are to be selected from different clusters.

Kudori *et al.* (2015) also clustered forty seven damask rose genotypes were in to three groups based on twelve morphological traits.

5.4.1. b. Cluster analysis based on qualitative characters in loose flower

The loose flower varieties were grouped into four clusters at 36 per cent similarity coefficient (Fig. 10). The varieties Arka Parimala, Vernish, Star Light and Red Varnish were grouped in to cluster I. They were similar with respect to the character red colour blend. Cluster III had four varieties Mirabel, Charisma, Spray Orange and Spray Yellow sharing similar characteristic of dense leaf margin. Cluster II and IV had only one member *viz*. Sherba Gold and Jadiov respectively. This is in confirmity with the findings of Baliyan *et al.* (2014) who clustered twenty four genotypes of chrysanthemum based on nine quantitative and five qualitative traits.

5.5. GENOTYPIC EVALUATION OF ROSE VARIETIES

Rose is adapted to temperate regions of Northern hemisphere. The ever increasing demand of this economically important cut flower in Kerala is met from the purchase of flowers from Banglore. There is a need to develop varieties suitable for warm humid regions of Kerala. The knowledge of variability, heritability and genetic advance are very important to evolve varieties having desirable traits. Hence genotypic evaluations of varieties were done which are discussed here under.

5. 5.1. GENETIC VARIABILITY

Genetic variability is the prerequisite factor in the success of any breeding programme. The parent selection should be based on variability as it results in recombination of desirable characters. The variability estimates *viz.* genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV)

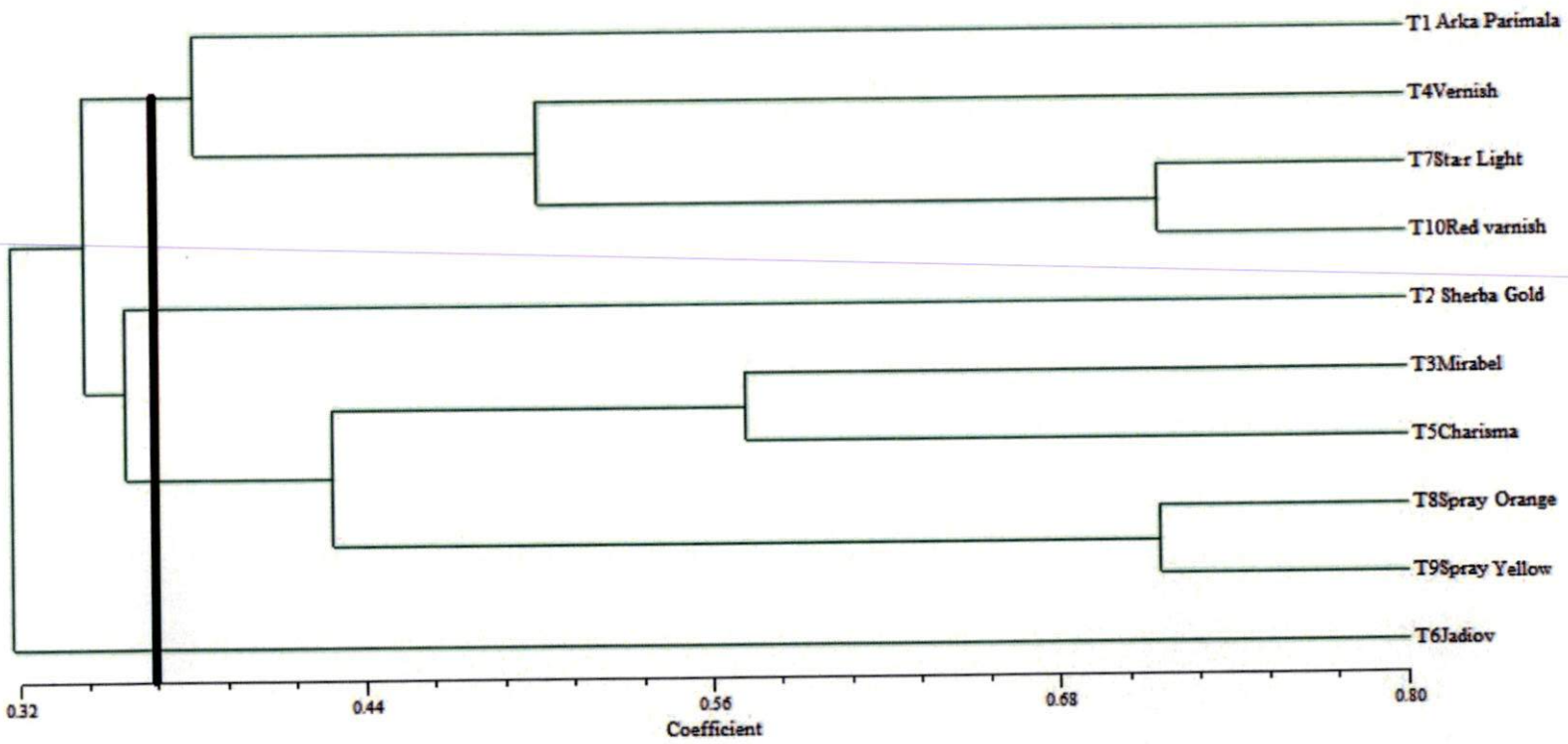


Figure 10. Dendrogram for qualitative characters for loose flower varieties

provides a measure of the variability in the population. High GCV and PCV for a character indicate higher variability in that character and selection will be effective based on this. Low GCV and PCV shows that the variability for that character in the population is low and selection based on this character will not be effective.

5.5.1.1. Cut flower

Among the cut flower varieties, all the characters showed a higher PCV than GCV indicating that the influence of environment in the expression of this character rather than its pure genetic makeup. These results are in agreement with the findings of Verma *et al*. (2008), Sewaniya,(2009) and Janaki, (2013) in rose.

The days taken for initiation to flower bud opening, shoot thickness and neck girth showed low GCV and PCV indicating low variability among the ten cut flower varieties and offers no scope for selection specific to this particular trait. Similar results of low GCV and PCV for bud opening was reported by Sewaniya, (2009).

Among the characters considered for cut flower, a higher value of GCV and PCV were observed for number of flowers per sprout (24.11, 32.30), number of petals per flower (40.08, 43.56), yield of marketable flowers (27.71, 48.86) and fresh weight of the flower (21.19, 23.61). This result reveals that there exist variability among the ten cut flower traits and opens wide scope for selection in breeding programme. Similar results for number of petals per flower was reported by, Palai *et al*. (2003) and Janaki, (2013) and yield of marketable flowers was reported by Zenali *et al*., (2009) and fresh weight of the flower by Panwar *et al.* (2012) and Janaki, (2013).

The neck length (10.63, 13.19) and vase life (15.70, 18.82) of the varieties had a moderate value of GCV and PCV indicating the presence of moderate variability in these characters. The moderate GCV for neck length was also reported by Janaki, (2013). For most of the characters *viz.* length and diameter of flower bud,

flower diameter at fully opened stage, flower persistence, duration of flowering, shoot length, stalk length and stalk girth low value of GCV and moderate PCV were reported. This result shows that the genetic variability in these characters is less and the expression of these characters is moderately influenced by environment.

5.5.1.2. Loose flower

Among loose flowers, higher GCV and PCV were observed for the characters *viz.* number of flowers per sprout (42.25, 52.45), number of flowers per plant (26.93, 34.43), number of petals per flower (55.42, 55.58), flower diameter at fully opened stage (25.89, 28.71), flower persistence (20.98, 27.65), yield of marketable flowers (20.98, 27.65), fresh weight of the flower (61.69, 93.84) and weight of petals per flower (83.81, 120.33). Similar results of high GCV and PCV for number of flowers per plant was reported by Sewaniya, (2009).

Length of flower bud (16.02, 14.57) and diameter of flower bud (17.49, 12.62) had moderate PCV and GCV indicating that there is moderate variability among the ten loose flower varieties for this character. The characters days taken for appearance to opening of flower buds (9.90, 6.73) and duration of flowering exhibited low PCV and GCV (8.12, 3.78) indicating that the variability in these characters was low.

5.5.2. HERITABILITY AND GENETIC ADVANCE

Heritability represents the portion of phenotypic variation that is due to genetic variation. Selection based on a character will be effective if its heritability is high. The heritability estimate helps to know the expression of various characters during selection. The genetic knowledge about rose is limited due to its complex nature of polyploidy, self-incompatibility, high heterozygosity, low seed set and poor germination. The traits *viz.* recurrent flowering, double flowers, double corolla, dwarfing, prickles on stem and petioles, yellow and pink flower colours, resistance to

black spot and powdery mildew were inherited by monogenic inheritance (Gudin, 2000 and Debener, 2003) whereas polygenic inheritance was reported for number of petals, winter hardiness and thorn density on shoots (Crespel *et al.*, 2002). The knowledge about the inheritance of major traits are essential for the choice of selection strategy in breeding programmes (Debener, 2003).

5.5.2.1. Cut flower

Among the cut flower varieties low heritability was observed for flower diameter at fully opened stage, flower persistence, duration of flowering, shoot length of the flower, shoot thickness, neck girth, stalk length and stalk girth. Similar results for number of flowers per plant was reported by Katiyar and Singh (2007).

High heritability was expressed by days taken from appearance to opening of flower buds (62.06), number of petals per flower (84.63), neck length (65.01) and fresh weight of the flower (80.56).Similar results of high heritability for number of petals per flower was reported by Babaei *et al.* (2008) and Janaki, (2013) and fresh weight of the flower was reported by Zeinali *et al.* (2009).

Moderate heritability was observed for the characters like length of flower bud, diameter of flower bud, number of flowers per sprout, number of flowers per plant and yield of marketable flowers. These results are in agreement with the findings of Janaki, (2013) for the characters diameter of flower bud and number of petals per flower.

Genetic gain under selection is represented by genetic advance. It indicates the level of improvement in the performance of progeny in the next generation. Genetic advance as percent of mean is used to compare genetic gain among various characters.

The characters number of flowers per sprout (37.06), number of flowers per plant (25.42) and number of petals per flower (75.95) exhibited higher genetic advance as per cent of mean. These results are in confirmity with the findings of

Sewaniya, (2009). Medium genetic advance as percent of mean was expressed for days taken for initiation to opening of flower buds, diameter of flower bud and neck length. Low genetic advance as percent of mean was found in length of flower bud, flower diameter at fully opened stage, shoot length, stalk length, stalk girth, duration of flowering and flower persistence.

High heritability coupled with high genetic advance indicated that the heritability is due to additive gene action and selection will be effective for these characters. The characters *viz.* number of petals per flower, fresh weight of the flower and vase life expressed high heritability with high genetic gain. Similar results for the characters like number of leaflets per plant, number of thorns per 30 cm of stalk, plant canopy and number of flowers per plant was reported by Sewaniya, (2009) and number of petals per flower was reported by Janaki, (2013).

In certain characters like days taken for appearance to opening of flower buds and neck length there was high heritability but moderate GAM which indicates that heritability is due to non additive gene action and selection based on these characters will not be effective.

Based on the estimation of genetic parameters it could be concluded that the traits with high genotypic correlation coefficient, Phenotypic correlation coefficient, heritability and genetic advance as percent of mean *viz.* number of petals per flower, fresh weight of the flower and vase life can be recommended as the selection criteria for the cut flowers.

5.5.2.2. Loose flower

Among the loose flower varieties high heritability was reported for the characters *viz.,* number of petals per flower (99.45), length of flower bud (82.73), flower diameter at fully opened stage (81.32), number of flowers per sprout (64.89), number of flowers per plant (61.19). These results are in agreement with the findings of Sewaniya, (2009) for number of petals per flower. Moderate heritability was reported in characters *viz.* days taken for appearance to opening of flower buds

(42.26), diameter of flower bud (47.57), yield of marketable flowers (57.58), fresh weight of the flower (48.50) and weight of petals per flower (48.50). Low heritability was reported in characters *viz.* flower persistence (10.86) and duration of flowering (21.59). These results are contradictory to the findings of Sewaniya, (2009) where more than 77 per cent heritability was observed for all the characters studied.

High genetic advance as percent of mean was reported in characters *viz.* weight of petals per flower (120.23), number of petals per flower (113.84), fresh weight of the flower (83.55), number of flowers per sprout (70.11), yield of marketable flowers (40.47) and length of flower bud (27.31). These results indicates that these characters can be improved through simple selection. Similar findings of high GAM was reported in number of petals per flower by Sewaniya, (2009) and Janaki, (2013) while high GAM for fresh weight of flower was reported by Janaki, (2013). Medium GAM was reported in diameter of flower bud (15.21) whereas low genetic advance as percent of mean was reported in duration of flowering (3.61), flower persistence (8.03) and days taken for appearance to opening of flower bud (9.43).

High heritability coupled with high GAM were noticed for characters, number of petals per flower (99.43, 113.84), number of flowers per sprout (64.89, 70.11), number of flowers per plant (61.19, 43.40) and flower diameter at fully opened stage (81.32, 48.10). The high heritability along with high GAM indicates that the heritability is due to additive gene effect and selection based on any of these characters will be effective. This was in agreement with the findings of Gogoi *et al.* (2016) who observed high heritability coupled with high genetic gain in number of flowers per plant per year, reported that the character is controlled by additive gene effect. Similar findings of high amount of genetic variation and heritability for the vigour related traits in rose was reported by Yan *et al.* (2005).

From the estimated genetic parameters for loose flower varieties, it could be concluded that the characters *viz.* number of flowers per plant, number of petals per

flower, flower diameter at fully opened stage having high GCV and PCV can be recommended as selection criteria. The high heritability coupled with high GAM results in effective selection to improve the performance of progeny in the next generation.

5.6. CORRELATION AND PATH ANALYSIS

The correlation study helps in selection through other characters affecting the desirable character. The positive correlation indicates that both traits can be improved simultaneously as the improvement in one may bring improvement in the correlated trait. The path coefficient analysis splits the correlation into direct and indirect effects.

5.6.1. Cut flower

The number of marketable flowers per plant was selected as the dependent variable. The path diagram for direct and indirect effect on number of marketable flowers by selected characters is depicted in Figure 11.

The results of path analysis indicated that the character number of flowers per plant (0.464, 0.456), plant height (0.580, 0.255) and number of sprouts per plant (0.557, 0.432) exhibited a strong positive correlation at genotypic and phenotypic levels also exhibited high direct positive effect on number of marketable flowers per plant (0.592, 0.384, 0.311 respectively) and these characters were of great importance for improvement in number of marketable flowers per plant.

The character fresh weight of the flower (0.803, 0.694), number of flowers per sprout (0.464, 0.456) and number of branches per plant (0.452, 0.275) exhibited a positive genotypic and phenotypic correlation and also exhibited a moderate direct effect (0.218, 0.298, and 0.275) on number of marketable flowers.

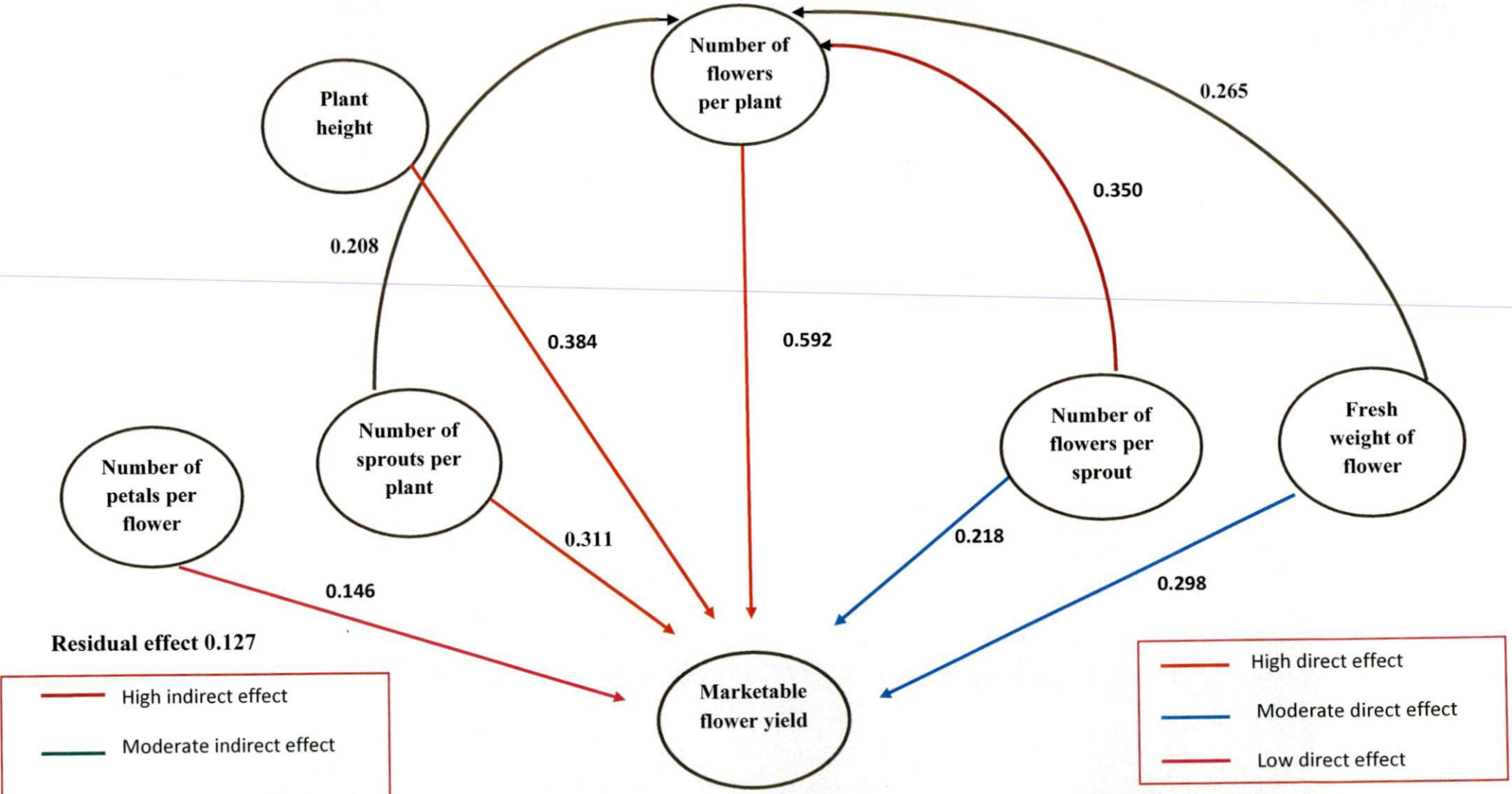


Figure 11. Path diagram for selected characters in cut flower rose

Number of petals per flower had a positive correlation with number of marketable flowers per plant (0.436, 0.412) which also exhibited a low direct positive effect (0.146).

Similar supporting results were reported by Sewaniya, (2009) as that number of flowering stalk per plant and plant height had strong positive correlation and high magnitude of positive direct effects on number of flowers per plant and hence can be opted as selection criteria for cut flowers whereas Janaki, (2013) reported that dry matter production per plant, total number of flowers per plant and fresh weight of single cut flower showed a high correlation and exerted a high positive direct effect and on flower yield per plant on fresh weight basis whereas The residual effects were 0.127 indicating, the selected ten flower yield attributing characters all together, contributed about 87 per cent variation of the flower yield per plant.

The results from genotypic and phenotypic correlation coefficient and path analysis indicated that the characters number of petals per flower and fresh weight of the flower had positive direct effect on number of marketable flowers per plant along with high GCV (%), PCV (%) heritability (%) and GAM (%) indicating that they can be adopted as selection criteria for improving number of marketable flowers per plant.

5.6.2. Loose flower

The marketable yield per plant was selected as the dependent variable. The path diagrams for direct and indirect effect on yield of marketable flowers by selected characters were depicted in Figure 12.

Among loose flower varieties a very high positive direct effect on marketable flower yield per plant was exhibited by plant height (3.055) and it was positively correlated to flower yield per plant at genotypic and phenotypic level (1.041,0.838).

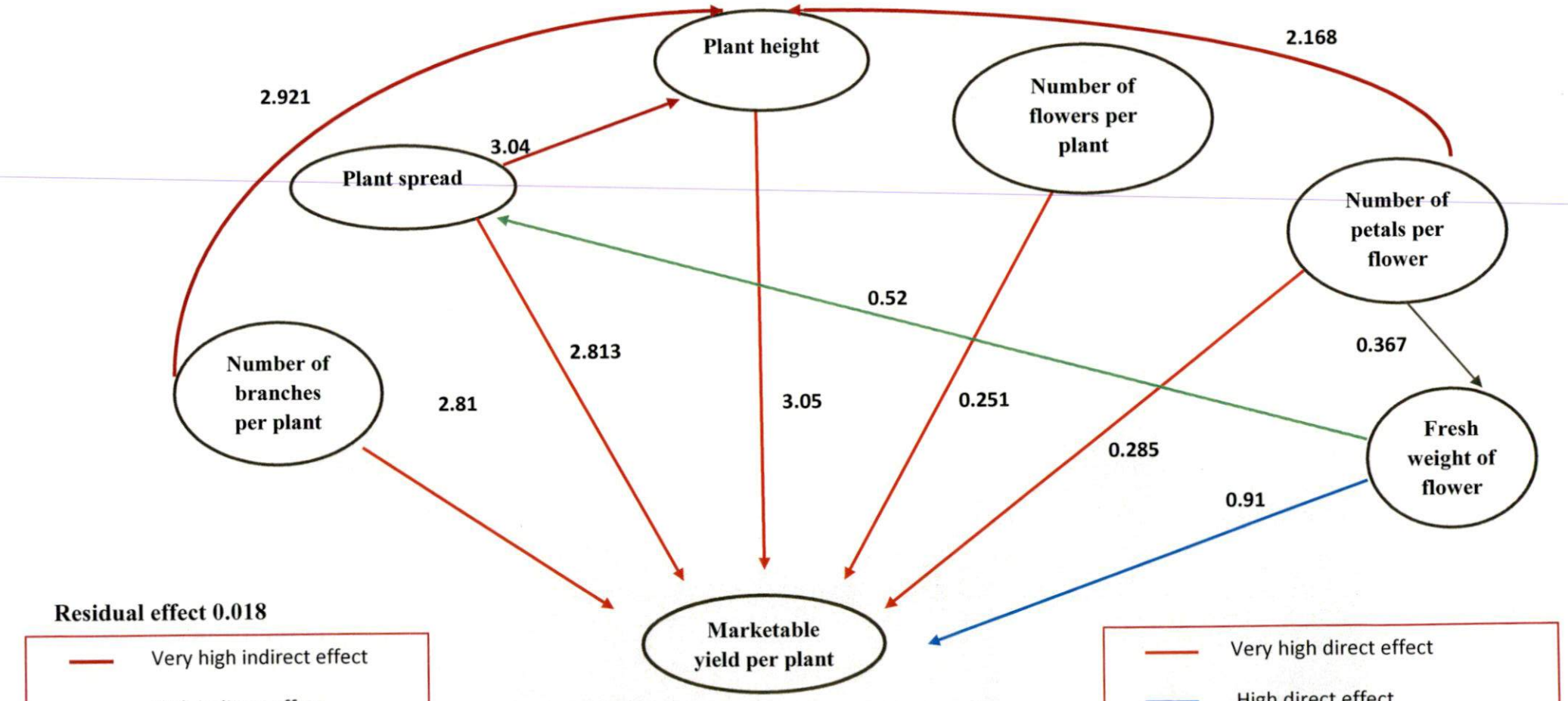


Figure 12. Path diagram for selected characters in loose flower rose

Very high positive direct effect (3.076) and positive correlation (1.045) were observed between diameter of flower bud and marketable yield per plant. The flower bud diameter also had a very high positive indirect effect (2.892) on flower yield per plant through very high positive direct effect (2.812) of plant spread.

The characters number of branches per plant (1.141) and length of flower bud (1.131) had very high positive direct effect on flower yield per plant and the correlation of these to marketable yield per plant was also positive.

The fresh weight of the flower exhibited high positive direct effect (0.910) and had significant and positive correlation to marketable yield per plant at genotypic and phenotypic level (0.104, 0.177).

The number of flowers per plant exhibited moderate positive direct effect (0.251) but the character had no significant correlation to marketable yield per plant at genotypic level. This character also showed very high positive indirect effect (1.080) through very high positive direct effect of plant spread (2.813).

The number of petals per flower exhibited moderate positive direct effect (0.285) and a positive correlation with marketable yield (0.669, .0.655) per plant. The number of sprouts had low positive direct effect (0.100) on marketable yield per plant and it was also positively (1.073, 0.875) and significantly correlated. There was a very high indirect positive effect (2.929) *via* very high positive direct effect (3.076) of flower bud diameter.

Similar supporting results of direct effect of number of branches per plant and number of leaves per branch on marketable yield were reported by Singh *et al.* (2001).

The residual effects were 1.83 indicating, the selected ten flower yield attributing characters all together contributed about 98 per cent of the variation in marketable flower yield per plant.

The results from genotypic and phenotypic correlation coefficients and path analysis indicated that the characters number of petals per flower and number of flowers per plant had significant and positive correlation and direct effect on yield of marketable flowers and these characters were also having high GCV (%), PCV (%) heritability (%) coupled with high genetic advance (%) and hence can be considered as the selection criteria for improving marketable yield per plant.

Summary

6. SUMMARY

Research work entitled Evaluation of rose varieties for commercial cultivation under the warm humid tropics of Kerala was conducted in a naturally ventilated polyhouse of Department of Floriculture and Landscaping, College of Horticulture, Vellanikkara, Thrissur during the period from September 2017 to March 2018. The objective of the study was to evaluate the performance of cut flower and loose flower rose varieties under polyhouse and to select suitable varieties of cut flower and loose flower types for commercial cultivation for the plains of Kerala.

The experiment was laid out in completely randomized design with six month old budded plants of ten cut flower and loose flower varieties each in three replications and fifteen plants in each treatment. The observations on various vegetative as well as floral parameters were taken and subjected to estimation of genetic parameters. The salient findings are summarized hereunder.

6.1. Cut flower

- The cut flower varieties varied significantly with respect to vegetative characters. Regarding plant height, there was no significant variation among varieties up to 6 month of planting. After 6 th month, the varieties Arka Pride, Taj Mahal and Emma were superior in terms of this parameter. The variety Gold Strike recorded lowest plant height among the ten varieties throughout the observation period.
- Eventhough there was no significant variation in plant spread among the varieties, superiority of the varieties Revival and Arka Swadesh could be observed in terms of this parameter at peak flowering stage (39.13 cm and 36.25 cm respectively).
- The highest number of sprouts was observed in Arka Ivory.
- Regarding number of branches per plant, there was no significant variation among the varieties during initial five months of planting and highest number

of branches per plant was observed in variety Revival from sixth month onwards.

- No significant variation in number of leaves per branch could be observed during the period of observation. However more number of leaves was observed in Arka Ivory.
- Varieties varied significantly with respect to qualitative vegetative characters.
- Upright growth habit was exhibited by variety Corvette whereas semi upright growth habit was observed in varieties Arka Ivory, Arka Pride, Noblesse and Taj Mahal. Other varieties were having spreading growth habit.
- Amout of prickles varied from many in varieties Arka Ivory, Arka Pride, Arka Swadesh and Noblesse, medium in varieties Gold Strike, Revival, Taj Mahal and Corvette and few in Peach Avalanche. Variety Emma was without any thorns.
- Variation in leaf colour ranging from light green, medium green, dark green and very dark green and varying degrees of serrations of leaf margin *viz.* fine, medium and dense were observed among the varieties. All the varieties were devoid of leaf hairiness.
- Significant variation was observed among varieties in number of days taken for initiation to opening of flower buds and the varieties Emma, Arka Ivory and Gold Strike recorded minimum number of days (11.73, 13.01 and 13.84 respectively) for initiation to opening of flower buds and the variety Peach Avalanche took highest number of days (15.11) from initiation to opening of flower buds.
- Length and diameter of flower bud was superior in Arka Ivory (2.73 cm, 1.09 cm) and Taj Mahal (2.53cm, 1.21 cm).
- There was significant variation in number of petals per flower and highest number of petals were observed in variety Taj Mahal (79.54) followed by Noblesse (38.2), Peach Avalanche (33.68), and Emma (30.33). The lowest

number of petals was observed in varieties Arka Pride (17.87) and Corvette (18.83) which were performing on par with each other.

- Neck length varied significantly among varieties and lowest neck length was observed in Gold Strike (4.31 cm).Varieties Emma and Arka Swadesh were performing on par with maximum neck length (7.36 cm and 6.61 cm respectively).
- There was significant variation in stalk length of cut flower varieties. Highest stalk length was observed in varieties Emma and Arka Pride (31.35 cm and 30.48 cm) which were performing on par with each other and lowest stalk length was observed in Gold Strike (21.84 cm).
- The girth of stalk, neck and shoot was not significantly different among the varieties.
- The number of flowers per sprout varied significantly among the varieties and the variety Revival (14.36) had highest number of sprouts per plant. The lowest number of flowers per sprout was observed in variety Gold Strike (4.46).
- Significant variations in number of flowers per plant were observed in cut flower varieties with highest number of flowers in varieties Revival (12.45), Arka Ivory (11.38), Arka Swadesh (10.10) and Peach Avalanche (9.86) which were performing on par with each other. The lowest numbers of flowers were obtained in Corvette (4.65).
- The yield of marketable flowers varied significantly among the cut flower cultivars. The varieties Arka Ivory (8.45) and Taj Mahal (8.23) were performing on par with highest number of marketable flowers. The lowest number of marketable flowers was observed in Corvette (6.56).
- The highest numbers of quality flowers were produced during the months of November- December in all the varieties except Noblesse and Gold Strike where highest numbers of quality flowers were produced during January.

- The fresh weight of the flowers varied significantly among the cut flower varieties and the highest fresh weight was observed in varieties Taj Mahal (8.08 g) and Noblesse (7.84 g) which were performing on par with each other. The least fresh weight was observed in variety Corvette (2.58 g).
- There was significant difference in the physiological loss in weight and it was highest in varieties Arka Ivory, Revival, Taj Mahal, Peach Avalanche, Peach Avalanche, Gold Strike and Arka Swadesh (3.35 g, 3.25 g, 2.97 g, 2.94 g, 2.75 g and 2.73 g respectively) whereas variety Arka Pride had lowest (1.68 g) physiological loss in weight.
- The vase life of the cultivars differed significantly among the cultivars and vase life was highest in varieties Revival (4.83 days), Taj Mahal (4.75 days) and Noblesse (4.75 days) and lowest vase life was observed in variety Corvette (2.5 days).
- Diversity analysis using dendrogram based on D2 statistics for both qualitative and quantitative characters indicated that there is wide variability among the cut flower varieties.
- High GCV (%) and PCV (%) were observed for the characters, number of flowers per sprout (24.11 and 32.30), number of petals per flower40.08 and (43.56), yield of marketable flowers (20.74, 24.04) and fresh weight of the flower (21.19 and 23.61)
- High heritability coupled with high genetic advance was exhibited by number of petals per flower (84.63, 75.95), fresh weight of the flower (80.56, 39.18) and vase life of the flower (69.53, 26.96).
- The characters number of flowers per sprout (0.464,0.456), number of flowers per plant (0.970,0.795), number of petals per flower (0.436,0.412), fresh weight of the flower (0.803,0.694) and number of sprouts per plant (0.557,0.432) exhibited significant and positive correlation on number of marketable flowers per plant at genotypic and phenotypic levels.

- The characters number of branches per plant, number of leaves per branch and plant height had significant positive correlation at genotypic level only (0.452, 0.462, and 0.580 respectively).
- High direct effect on number of marketable flowers per plant was exhibited by number of flowers per plant (0.592), plant height (0.384) and number of sprouts per plant (0.311) whereas moderate direct effect was exhibited by number of flowers per sprout (0.218) and fresh weight of the flower (0.298) and number of branches per plant (0.275). Low positive direct effect (0.146) was exhibited by number of petals per flower.
- Since the characters number of petals per flower and fresh weigh of the flower had high GCV (%), PCV (%), heritability (%) coupled with genetic gain (%) along with positive and significant correlation and direct effect on number of marketable flowers per plant, these characters can be fixed as selection criteria for improving marketable yield per plant.

6.2. Loose flowers

- Plant height at flower emergence and at peak flowering was superior in variety Arka Parimala (59.82 cm) whereas lowest plant height was observed in varieties Mirabel (28.08 cm) and Red Varnish (32.83 cm).
- The plant spreads of the varieties were not significantly different at flower emergence and at peak flowering and the variety Arka Parimala was superior in plant spread during both the time periods.
- The varieties Star Light and Charisma were having highest number of sprouts at flower emergence period whereas at peak flowering, highest number of sprouts was observed in variety Charisma (4) followed by Star Light (2.83).
- The varieties Mirabel and Star Light had highest number of branches at flower emergence whereas at peak flowering, highest number of branches was in variety Arka Parimala (6.67) and Jadiov (6.5).

177

- Highest number of leaves at flower emergence and at peak flowering was in variety Star Light (50.83, 44.47) and Vernish (52.33, 41.17).
- Lowest numbers of days from initiation to opening of flower buds were observed in varieties Charisma, Spray Yellow, Spray Orange, Star Light, Mirabel and Arka Parimala (13.03, 13.08, 13.36, 13.7, 13.75, and 14.8 respectively).
- The flower persistence of loose flower varieties varied significantly and the highest flower persistence was in varieties Sherba Gold, Mirabel, Charisma, (11.96, 11.37, and 9.55) which were performing on par with each other. The lowest flower persistence was reported in Arka Parimala (5.38 days).
- Varieties differed significantly in duration of flowering and highest duration of flowering was observed in varieties Spray Orange, Red Varnish, Charisma, Mirabel, Arka Parimala, Vernish and Star Light (203.7, 202, 201.7, 200.7,199.3, 197.3 and 191.7 days respectively) which were performing on par with each other.
- Arka Parimala recorded highest bud length (2.63 cm) and lowest length of flower bud was observed in Star Light (1.6 cm).
- The highest diameter of flower bud was observed in variety Sherba Gold (1.03 cm) and Charisma (9.06 cm), Star Light (0.92 cm) and Vernish (0.92 cm) which were performing on par with each other. Lowest flower bud diameter was observed in Spray Orange (0.69 cm).
- Significant differences in number of petals were observed among loose flower varieties and the variety Star Light recorded highest number of petals (101.0). The lowest numbers of petals were observed in variety Arka Parimala (15.4).
- The loose flower varieties showed significant difference among flower diameter at fully opened stage. Arka Parimala recorded highest flower diameter (6.67 cm) followed by Star Light (4.84 cm), Sherba Gold (4.13 cm)

and Vernish (4.09 cm). The lowest flower diameter was observed in Spray Yellow (2.83 cm).

- Significant variation in number of flowers per sprout was obtained among loose flower varieties and highest number of flowers per sprout was observed in Vernish (20.82), Mirabel (20.55), Spray Orange (18.6) and Spray Yellow (17.98) which were performing on par with each other. The least number was reported in Star Light (3.31).
- Regarding number of flowers per plant, the variety Red Varnish (27.8) had highest numbers of flowers followed by Mirabel (24.2). The lowest number of flowers was observed on Star Light (9.95).
- Highest yield of marketable flowers were observed in varieties Arka Parimala (34.33 g). Lowest marketable yield was obtained in variety Jadiov (11.39 g).
- The fresh weight of the flower significantly varied among the loose flower varieties and highest fresh weight was observed in the variety Star Light (3.16 g) and Arka Parimala (3.14 g) followed by Sherba Gold (2.64). The lowest fresh weight was recorded in variety Spray Yellow (1.13 g).
- Significant differences in number of petals were observed among loose flower varieties and the variety Star Light recorded highest number of petals (101.0). The lowest numbers of petals were observed in variety Arka Parimala (15.4).
- Weight of petals significantly differed among the loose flower varieties and highest weight of petals was observed in variety Star Light (2.78 g), followed by Arka Parimala (1.94 g) and Sherba Gold (1.83 g). The lowest number of petals was observed in variety Spray Yellow (0.683 g).
- Regarding shelf life, no significant variation could be observed among the varieties.
- The qualitative characters varied among the varieties and variety Arka Parimala was found to be with strong fragrance.

- Diversity analysis using dendrogram based on D^2 statistics indicated that there was wide variability among the loose flower varieties for both quantitative and qualitative characters
- Higher PCV and GCV were observed for the characters number of flowers per sprout (52.45, 42.25), number of flowers per plant (34.43, 26.93), number of petals per flower (55.58, 55.42), flower diameter at fully opened stage (28.71, 25.89), flower persistence (27.65, 20.98), yield of marketable flowers (27.65, 20.98), fresh weight of the flower (93.84, 61.69) and weight of petals per flower (120.33, 83.81).
- High heritability coupled with high GAM was reported in characters number of petals per flower (99.43, 113.84), number of flowers per sprout (64.89, 70.11), number of flowers per plant (61.19, 43.40), length of flower bud (82.73, 27.31) and flower diameter at fully opened stage (81.32, 48.10).
- Correlation study revealed that the characters number of flowers per plant and number of petals per plant had a significant and positive correlation with marketable yield at genotypic and phenotypic levels (0.156, 0.111 and 0.669, 0.655 respectively)
- Path analysis indicated that the characters plant height (3.055), plant spread (2.813), number of branches per plant (1.141), length (1.131) and diameter of flower bud (3.076) had very high positive direct effect on marketable yield per plant. Fresh weight of flower (0.910) had high positive direct effect whereas number of flowers per plant and number of petals had moderate positive direct effect on marketable yield (0.251, 0.285 respectively).
- Since the characters number of flowers per plant and number of petals per flower had high GCV (%), PCV (%), high heritability (%) coupled with genetic gain (%) along with positive significant correlation and direct positive effect on marketable yield, these characters can be fixed as the selection criteria for loose flowers.

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Appendices

APPENDIX 1

Table 1. Plant height of the cut flower varieties during 2017 September to 2018 March

Treatment	Months of observation																	
	September		October		November		December		Janauary		February		March		April		May	
	1st Fort night	2nd Fort night	1st Fort night	2nd Fort night	1st Fort night	2nd Fort night	1st Fort night	2nd Fort night	1st Fort night	2nd Fort night	1st Fort night	2nd Fort night	1st Fort night	2nd Fort night	1st Fort night	2nd Fort night	1st Fort night	2nd Fort night
T_1 (Arka Ivory)	27.50	31.83	32.33	33.67	16.92	30.00	34.67	39.00	39.83	40.00	40.17	41.5	42.5	42.75	42.67	42.75	43.67	43.85
T_2 (Arka Pride)	31.67	31.90	32.67	38.33	21.17	30.00	37.67	45.00	46.83	44.83	52.43	53.50	51.25	51.17	58.17	62.25	52.50	52.75
T_3 (ArkaSwadesh)	29.50	35.67	37.00	39.00	22.87	31.00	36.08	37.83	41.43	42.00	42.05	42.33	43.33	45.17	45.33	43.50	49.33	49.55
T_4 (Gold Strike)	24.00	25.17	30.33	31.25	19.33	33.08	36.75	37.17	37.33	37.38	37.42	38.50	39.83	39.83	39.85	40.55	41.75	43.92
T_5 (Noblesse)	30.50	35.33	35.67	38.50	21.58	37.33	38.50	40.67	41.75	43.32	35.92	40.83	45.08	47.33	44.00	46.50	43.67	43.75
T_6 (Revival)	25.17	31.17	36.83	37.83	20.33	25.17	34.58	40.17	42.25	43.00	43.75	46.33	39.67	43.17	44.17	44.42	44.50	44.75
T_7 (TajMahal)	25.67	29.50	32.83	35.33	21.17	37.50	39.50	43.33	46.08	48.83	49.17	52.00	53.92	56.67	56.78	57.58	57.75	57.83
T_8 (Corvette)	31.17	35.83	36.50	38.00	20.00	26.50	31.33	33.75	34.50	34.85	35.00	38.83	39.58	44.83	45.00	46.00	46.55	46.78
T_9 (Emma)	32.83	35.33	37.50	38.17	19.33	29.67	32.75	35.92	36.58	37.83	40.33	41.67	45.25	48.17	54.17	56.58	56.83	57.08
T_{10}(Peach Avalanche)	28.17	32.50	37.00	37.92	25.70	27.33	32.67	35.67	36.82	37.55	38.57	39.00	39.88	42.50	42.67	42.85	42.92	43.75
CV	**17.98**	**17.63**	**15.13**	**14.69**	**13.98**	**15.31**	**16.49**	**15.25**	**16.78**	**16.57**	**13.83**	**18.46**	**12.47**	**10.16**	**12.89**	**16.44**	**13.07**	**15.09**
CD (5%)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**9.77**	**NS**	**9.23**	**8.02**	**NS**	**18.44**	**10.20**	**NS**

Table 2. Plant spread of cut flower varieties during 2017 September to 2018 May

Treatment	Months of observation																	
	September		October		November		December		Janauary		February		March		April		May	
	1st Fort night	2nd Fort night	1st Fort night	2nd Fort night	1st Fort night	2nd Fort night	1st Fort night	2nd Fort night	1st Fort night	2nd Fort night	1st Fort night	2nd Fort night	1st Fort night	2nd Fort night	1st Fort night	2nd Fort night	1st Fort night	2nd Fort night
T_1 (Arka Ivory)	18.08	22.08	22.00	23.88	10.79	23.67	26.00	31.17	27.67	28.83	24.71	29.67	28.17	31.17	30.92	30.00	29.75	30.25
T_2 (Arka Pride)	18.42	22.80	21.17	29.00	11.75	22.42	25.92	26.75	25.17	25.83	27.25	30.67	33.25	33.50	36.42	31.92	34.08	33.17
T_3 (ArkaSwadesh)	18.83	20.58	19.67	22.96	12.42	22.42	30.17	28.50	29.67	34.42	27.83	29.83	31.58	31.17	38.08	30.50	36.58	34.54
T_4 (Gold Strike)	14.25	21.00	21.25	24.08	12.04	27.58	27.92	29.00	29.33	27.13	24.75	28.58	27.50	28.50	29.17	28.50	29.67	32.38
T_5 (Noblesse)	16.17	17.75	19.08	22.58	12.67	19.83	19.08	23.00	24.46	21.58	21.79	19.58	19.67	22.17	22.50	20.79	23.50	21.92
T_6 (Revival)	13.42	18.83	23.25	24.42	15.67	25.33	27.33	29.57	28.04	32.42	31.00	30.17	29.92	33.50	30.42	30.08	31.83	31.42
T_7 (TajMahal)	14.08	17.92	19.83	23.58	17.96	24.83	24.21	23.54	27.75	29.04	24.50	28.00	25.29	26.17	27.17	26.17	25.17	25.17
T_8 (Corvette)	13.25	18.33	17.00	18.50	12.58	16.00	20.58	21.83	20.42	22.83	20.50	22.75	25.08	22.92	23.83	20.75	22.50	24.25
T_9 (Emma)	14.17	16.92	17.00	18.67	11.67	18.17	21.33	21.92	21.50	25.67	23.79	22.08	24.50	30.08	24.83	24.50	27.17	26.83
T_{10}(Peach Avalanche)	15.58	21.67	21.58	26.25	15.13	23.50	25.04	26.42	28.50	27.92	26.02	23.96	28.33	28.58	30.08	30.50	27.33	27.00
CV	**NS**	**NS**	**3.81**	**NS**	**NS**	**4.96**	**6.43**	**5.07**	**NS**	**NS**	**NS**	**NS**	**6.55**	**NS**	**8.08**	**5.84**	**7.83**	**7.66**
CD (5%)	**16.68**	**13.77**	**11.08**	**15.04**	**16.56**	**13.02**	**15.26**	**11.38**	**16.90**	**19.00**	**18.99**	**18.51**	**14.08**	**17.50**	**16.16**	**12.53**	**15.99**	**15.67**

Table 3. Number of sprouts of the cut flower varieties during 2017 September to 2018 May

Treatments	Months of observation																	
	September		October		November		December		Janauary		February		March		April		May	
	1st Fort night	2nd Fort night	1st Fort night	2nd Fort night	1st Fort night	2nd Fort night	1st Fort night	2nd Fort night	1st Fort night	2nd Fort night	1st Fort night	2nd Fort night	1st Fort night	2nd Fort night	1st Fort night	2nd Fort night	1st Fort night	2nd Fort night
T_1(ArkaIvory)	2.00	1.50	2.33	1.83	2.00	2.17	2.00	2.17	2.00	2.00	2.00	2.17	2.33	2.50	2.33	2.33	2.50	2.00
T_2(Arka Pride)	1.17	1.17	1.33	1.00	1.00	1.33	1.00	1.33	1.50	1.33	1.67	1.83	1.67	1.67	1.83	1.50	1.67	2.00
T_3(ArkaSwadesh)	1.17	1.33	1.17	1.33	1.00	1.17	1.00	1.17	1.83	1.67	1.67	1.67	1.50	1.67	1.67	2.00	1.83	1.50
T_4(Goldstrike)	1.17	1.17	1.50	1.50	1.17	2.00	1.17	2.00	2.17	2.17	2.83	2.00	2.33	3.00	2.83	2.33	3.00	2.00
T_5 (Noblesse)	1.00	1.00	1.00	1.00	1.50	1.00	1.50	1.00	1.33	1.33	1.67	1.83	1.33	2.00	1.50	1.50	1.67	1.50
T_6 (Revival)	1.00	1.00	1.00	1.00	1.83	1.00	1.83	1.00	1.17	1.17	1.33	1.33	1.67	1.17	1.33	1.67	1.33	1.50
T_7(TajMahal)	1.00	1.00	1.00	1.00	1.67	1.17	1.67	1.17	1.17	1.83	1.50	2.00	1.83	1.67	1.67	1.67	1.33	1.67
T_8(Corvette)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.17	1.00	1.17	1.17	1.17	1.17	1.50	1.33	1.00
T_9(Emma)	1.00	1.00	1.00	1.00	1.17	1.00	1.17	1.00	1.17	1.17	1.17	1.33	1.33	1.33	1.50	1.33	1.33	1.33
T_{10}(Peach Avalanche)	1.00	1.00	1.33	1.33	1.17	1.50	1.17	1.50	2.00	1.83	2.17	1.50	2.17	2.00	2.17	2.33	2.17	2.17
CD (5%)	**0.38**	**NS**	**0.78**	**0.47**	**NS**	**0.41**	**NS**	**0.41**	**0.38**	**NS**	**0.68**	**NS**	**NS**	**0.89**	**0.96**	**NS**	**0.79**	**NS**
CV	**15.44**	**17.63**	**15.13**	**14.69**	**13.99**	**12.31**	**16.49**	**15.25**	**16.78**	**16.57**	**13.83**	**18.46**	**12.47**	**10.16**	**12.89**	**12.44**	**13.07**	**15.09**

Table 4. Number of branches of the cut flower varieties during 2017 September to 2018 May

Treatments	Months of observation																	
	September		October		November		December		Janauary		February		March		April		May	
	1 st Fort night	2nd Fort night	1 st Fort night	2nd Fort night	1 st Fort night	2nd Fort night	1 st Fort night	2nd Fort night	1 st Fort night	2nd Fort night	1 st Fort night	2nd Fort night	1 st Fort night	2nd Fort night	1 st Fort night	2nd Fort night	1 st Fort night	2nd Fort night
T_1(ArkaIvory)	2.33	2.67	3.33	3.50	1.83	3.67	3.00	4.00	3.00	3.67	3.17	7.00	6.50	6.83	7.83	7.17	7.50	6.83
T_2(Arka Pride)	2.00	2.83	3.00	2.67	3.00	4.33	3.33	3.25	3.33	4.83	2.67	4.67	4.67	5.33	5.50	4.83	5.67	5.33
T_3(ArkaSwadesh)	1.83	2.67	2.50	3.00	4.00	3.50	5.33	3.50	5.33	3.50	3.83	6.17	6.67	6.33	8.33	8.67	8.83	8.50
T_4(Gold Strike)	2.17	3.00	2.83	3.00	2.67	4.33	5.67	3.67	5.67	3.67	4.17	6.50	6.33	6.50	7.33	8.00	7.17	7.83
T_5 (Noblesse)	1.33	2.00	2.50	2.83	2.83	3.67	3.50	2.33	3.50	2.33	3.33	3.50	5.33	6.33	5.00	5.83	5.83	5.00
T_6 (Revival)	1.83	2.00	3.50	3.67	3.83	3.83	5.33	5.50	5.33	5.00	5.33	6.83	10.67	11.67	12.00	12.00	10.50	12.00
T_7(TajMahal)	2.33	2.67	3.33	3.33	3.00	3.50	4.83	3.50	4.83	3.17	3.00	4.83	5.33	6.33	6.67	5.00	5.00	7.17
T_8(Corvette)	1.50	2.00	2.17	1.83	2.50	2.50	3.17	2.58	3.17	2.50	2.83	4.17	5.50	4.83	4.67	4.00	5.33	5.33
T_9(Emma)	1.83	1.83	3.00	3.00	2.17	4.00	7.83	4.50	7.83	4.17	4.17	5.17	5.50	7.00	6.67	6.00	8.33	5.83
T_{10}(Peach Avalanche)	2.00	3.83	4.17	3.67	3.83	6.17	5.67	5.00	5.67	4.50	5.17	7.50	9.00	9.83	10.33	11.17	11.00	11.67
CD (5%)	**0.56**	**NS**	**NS**	**NS**	**NS**	**1.48**	**NS**	**0.87**	**NS**	**NS**	**1.50**	**2.42**	**NS**	**3.96**	**2.93**	**3.23**	**3.91**	**3.96**
CV	**17.17**	**16.31**	**17.52**	**13.18**	**14.39**	**18.91**	**16.88**	**13.54**	**16.88**	17.16	**13.72**	**15.26**	16.11	**12.70**	**13.13**	**15.08**	**15.55**	**18.90**

Table 5. Number of leaves/branch of the cut flower varieties during 2017 September to 2018 May

Treatments	Months of observation																	
	September		October		November		December		Janauary		February		March		April		May	
	1st Fort night	2nd Fort night	1st Fort night	2nd Fort night	1st Fort night	2nd Fort night	1st Fort night	2nd Fort night	1st Fort night	2nd Fort night	1st Fort night	2nd Fort night	1st Fort night	2nd Fort night	1st Fort night	2nd Fort night	1st Fort night	2nd Fort night
T_1(ArkaIvory)	29.50	32.33	31.67	28.67	4.67	32.50	21.00	20.00	39.17	34.33	17.33	19.33	20.50	19.83	25.17	19.33	21.33	13.00
T_2(Arka Pride)	20.17	26.83	25.83	33.33	7.33	24.83	24.50	27.50	27.33	23.83	28.83	23.17	23.67	23.00	24.33	12.33	24.00	14.50
T_3(ArkaSwadesh)	24.00	30.83	30.67	29.83	2.83	21.83	30.00	30.5	35.00	40.33	19.67	20.00	22.00	17.67	24.17	17.33	23.17	21.17
T_4(Gold Strike)	21.83	23.67	29.17	29.83	4.50	31.17	24.50	30.33	25.17	24.33	23.67	23.17	21.83	18.33	22.00	15.00	18.67	21.17
T_5 (Noblesse)	39.50	36.17	29.50	40.50	2.50	25.83	28.50	22.67	34.17	31.67	25.50	21.17	17.17	18.67	20.33	13.33	21.83	18.50
T_6 (Revival)	22.83	20.67	22.00	29.50	3.67	27.00	19.33	21.67	25.50	26.50	20.83	17.83	15.50	18.50	25.00	18.67	15.33	22.50
T_7(TajMahal)	23.33	25.33	20.50	29.33	12.33	27.00	19.17	23.00	26.17	27.00	25.83	23.33	22.17	23.33	24.17	12.17	30.67	14.00
T_8(Corvette)	31.67	28.33	23.50	29.00	3.50	14.50	16.33	16.67	27.00	21.67	15.00	17.33	20.67	12.83	17.83	9.67	14.33	13.83
T_9(Emma)	23.17	25.33	22.83	25.33	4.33	17.17	18.83	16.00	20.83	23.67	21.50	16.00	11.33	14.33	14.50	12.17	7.20	12.67
T_{10}(Peach Avalanche)	23.83	22.83	20.00	25.83	9.17	24.50	18.17	16.33	24.67	19.67	15.33	19.50	16.17	13.75	21.00	11.00	10.50	11.17
CD(5%)	**NS**	**NS**	**NS**	**NS**	**NS**	**9.46**	**NS**	**NS**	**NS**	**9.81**	**NS**	**NS**	**NS**	**NS**	**NS**	**5.52**	**NS**	**7.701**
CV	**10.51**	**16.92**	**14.09**	**12.17**	**15.04**	**12.45**	**17.81**	**18.74**	**14.36**	**11.08**	**14.81**	**17.08**	**11.57**	**16.48**	**12.97**	**16.83**	**13.25**	**17.34**

APPENDIX II

Table 1. Plant height of the loose flower varieties during 2017 September to 2018 May

Treatment	Months of observation																	
	September		October		November		December		Janauary		February		March		April		May	
	1st Fort night	2nd Fort night	1st Fort night	2nd Fort night	1st Fort night	2nd Fort night	1st Fort night	2nd Fort night	1st Fort night	2nd Fort night	1st Fort night	2nd Fort night	1st Fort night	2nd Fort night	1st Fort night	2nd Fort night	1st Fort night	2nd Fort night
T1 (ArkaParimala)	29.50	28.00	27.50	33.67	20.00	36.50	48.37	47.80	53.33	59.82	52.53	55.50	55.33	53.67	66.67	68.67	71.00	65.17
T_2 (Sherba Gold)	22.33	26.17	26.67	38.33	16.00	30.17	30.60	34.08	36.83	38.95	36.67	33.08	29.67	30.17	34.17	28.75	28.83	30.10
T_3 (Mirabel)	22.50	30.33	27.67	39.17	19.08	28.67	30.72	33.58	29.77	30.83	32.00	28.67	28.17	26.50	25.83	27.83	28.33	28.50
T_4 (Vernish)	22.33	29.00	30.67	31.25	18.67	30.17	41.58	46.33	48.33	47.05	43.68	38.50	45.00	43.17	43.17	41.00	40.42	43.42
T_5 (Charisma)	20.17	25.67	32.17	38.50	18.83	30.67	33.97	37.17	40.08	38.08	35.83	37.17	34.83	34.67	34.75	33.75	35.00	34.50
T_6 (Jadiov)	24.83	31.00	31.17	41.17	17.17	33.50	37.75	39.75	48.00	48.17	46.00	42.75	46.00	45.83	47.83	46.50	42.92	37.00
T_7 (Star Light)	26.50	30.00	28.83	35.33	20.33	38.50	45.33	47.92	56.17	52.72	52.13	49.50	46.32	40.33	31.75	34.83	34.67	31.83
T_8 (Spray Orange)	26.50	32.00	26.83	37.67	16.67	35.83	34.75	33.42	38.33	39.25	41.83	37.42	37.42	41.67	40.33	39.00	38.83	38.33
T_9 (SprayYellow)	21.25	27.17	25.50	38.17	15.75	26.83	35.03	38.75	39.92	40.50	34.72	27.72	28.83	26.08	24.33	25.00	25.00	28.83
T_{10} (Red Varnish)	25.25	33.67	26.83	37.92	18.83	29.33	32.42	39.25	40.00	36.00	36.97	37.83	35.33	35.67	35.00	35.58	33.83	33.50
CV	**15.88**	**13.04**	**16.79**	**15.81**	**14.09**	**15.64**	**17.99**	**20.27**	**17.31**	**14.13**	**18.90**	**17.72**	**16.87**	**16.44**	**18.26**	**17.92**	**15.68**	**16.22**
CD(5%)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**11.35**	**NS**	**12.70**	**10.38**	**13.28**	**11.71**	**11.12**	**10.58**	**15.86**	**14.87**	**15.28**	**16.57**

Table 2. Plant spread of loose flower varieties during 2017 September to 2018 May

Treatment	Months of observation																	
	September		October		November		December		Janauary		February		March		April		May	
	1st Fort night	2nd Fort night	1st Fort night	2nd Fort night	1st Fort night	2nd Fort night	1st Fort night	2nd Fort night	1st Fort night	2nd Fort night	1st Fort night	2nd Fort night	1st Fort night	2nd Fort night	1st Fort night	2nd Fort night	1st Fort night	2nd Fort night
T1(ArkaParimala)	18.58	20.78	22.58	23.88	15.50	26.75	54.00	56.83	29.33	33.17	24.29	27.67	27.42	30.08	29.67	32.25	37.67	31.25
T2(Sherba Gold)	18.17	20.25	21.25	29.00	15.71	23.92	53.00	55.00	30.25	33.50	23.17	21.08	21.58	23.42	20.33	21.54	22.25	18.17
T_3(Mirabel)	14.83	19.42	20.50	22.96	13.54	24.08	58.33	58.17	31.50	27.42	26.17	26.25	26.92	21.92	25.50	25.42	26.58	26.00
T_4(Vernish)	15.42	18.17	21.83	24.08	17.06	27.75	66.00	65.83	34.17	34.42	29.50	30.29	29.33	30.00	29.00	29.33	29.17	26.25
T_5(Charisma)	14.67	18.33	19.92	22.58	18.21	26.25	54.17	52.83	27.67	29.08	27.50	24.83	23.83	22.08	24.75	23.21	24.58	23.92
T_6(Jadiov)	15.83	19.33	19.67	24.42	14.25	23.67	51.83	54.50	27.17	28.33	27.17	22.83	23.17	23.42	23.25	24.17	24.17	20.83
T_7(Starlight)	15.07	19.83	20.00	23.58	16.08	27.58	62.17	62.17	31.42	31.83	25.83	22.08	26.92	23.75	19.75	23.50	22.58	19.92
T_8(Spray Orange)	18.33	21.17	23.42	18.50	14.58	24.79	51.17	51.67	28.08	28.83	23.25	27.00	25.25	26.58	27.33	26.50	26.67	25.67
T_9(Spray Yellow)	16.92	19.58	23.50	18.67	15.88	22.42	52.67	54.17	32.33	30.33	24.46	21.33	21.17	22.25	19.50	19.04	20.83	23.54
T_{10}(Red Varnish)	14.67	20.83	21.83	26.25	10.17	22.75	48.33	53.83	27.67	25.71	24.42	24.08	23.00	23.67	22.83	20.75	21.42	21.58
CD (5%)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**5.79**	**8.51**	**NS**
CV	**13.36**	**12.90**	**12.09**	**14.95**	**22.58**	**12.36**	**14.18**	**12.49**	**9.76**	**12.30**	**17.29**	**15.98**	**15.23**	**17.24**	**17.49**	**13.84**	**19.52**	**20.51**

Table 3. Number of sprouts of the loose flower varieties during 2017 September to 2018 May

Treatment	Months of observation																	
	September		October		November		December		Janauary		February		March		April		May	
	1st Fort night	2nd Fort night	1st Fort night	2nd Fort night	1st Fort night	2nd Fort night	1st Fort night	2nd Fort night	1st Fort night	2nd Fort night	1st Fort night	2nd Fort night	1st Fort night	2nd Fort night	1st Fort night	2nd Fort night	1st Fort night	2nd Fort night
T1(ArkaParimala)	1.67	1.33	1.50	1.83	1.67	1.33	1.67	1.50	1.67	1.50	1.833	2.00	2.00	2.00	2.33	2.00	2.17	2.00
T2(Sherba Gold)	1.33	1.17	1.33	1.00	1.17	1.17	1.50	1.83	1.50	1.83	2.000	1.50	2.00	1.50	2.33	2.83	2.17	1.50
T_3(Mirabel)	1.00	1.00	1.00	1.33	1.17	1.00	1.17	1.17	1.17	1.17	2.333	2.17	2.00	2.33	2.50	2.00	2.00	1.83
T_4(Vernish)	1.00	1.17	1.17	1.50	1.33	1.17	1.33	1.33	1.33	1.33	2.333	2.00	2.50	2.17	2.33	2.17	1.17	2.17
T_5(Charisma)	1.00	1.00	1.00	1.00	2.33	2.00	3.00	2.67	3.00	2.67	3.500	3.83	3.33	3.33	3.17	3.17	3.33	3.00
T_6(Jadio)	1.17	1.33	1.67	1.00	2.00	1.83	1.83	1.83	1.83	1.83	2.333	2.67	2.67	2.83	2.67	2.67	2.50	2.00
T_7(Star Light)	1.00	1.50	1.67	1.00	2.17	2.17	4.00	2.67	4.00	2.67	3.000	2.67	3.50	3.33	2.50	2.50	2.50	2.00
T_8(Spray Orange)	1.00	1.17	1.33	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.000	1.33	1.17	1.83	1.17	1.50	1.50	1.67
T_9(Spray Yellow)	1.00	1.33	1.00	1.00	1.33	1.00	1.00	1.17	1.00	1.17	1.833	2.17	1.67	1.67	2.00	1.67	2.17	1.33
T_{10}(Red Varnish)	1.17	1.50	2.00	1.33	2.00	1.67	2.00	2.00	2.00	2.00	2.167	2.17	2.17	2.00	1.83	1.83	1.83	1.83
CD (5%)	**NS**	**NS**	**NS**	**0.47**	**0.73**	**0.60**	**NS**	**0.82**	**NS**	**0.82**	**0.852**	**0.87**	**1.13**	**0.87**	**0.98**	**1.01**	**1.01**	**NS**
CV	**13.47**	**15.98**	**17.79**	**12.82**	**16.48**	**14.67**	**11.67**	**18.13**	12.67	**14.13**	13.38	**12.59**	**26.89**	**12.01**	**12.28**	**18.03**	**17.73**	13.38

Table 4. Number of branches of the loose flower varieties during 2017 September to 2018 May

Treatment	Months of observation																	
	September		October		November		December		Janauary		February		March		April		May	
	1st Fort night	2nd Fort night	1st Fort night	2nd Fort night	1st Fort night	2nd Fort night	1st Fort night	2nd Fort night	1st Fort night	2nd Fort night	1st Fort night	2nd Fort night	1st Fort night	2nd Fort night	1st Fort night	2nd Fort night	1st Fort night	2nd Fort night
T1(ArkaParimala)	3.50	2.33	3.83	3.50	3.33	4.17	5.33	7.17	5.00	7.17	5.50	7.17	7.50	7.67	9.00	11.00	13.83	9.50
T2(Sherba Gold)	1.83	2.00	2.00	2.67	2.00	3.17	4.83	4.67	4.17	4.67	3.67	4.67	6.17	5.33	5.50	3.67	4.50	3.83
T_3(Mirabel)	2.33	3.00	4.00	3.00	4.50	6.00	9.00	7.67	5.67	7.67	4.67	6.17	7.00	7.00	8.83	8.67	9.00	8.33
T_4(Vernish)	1.83	3.17	3.83	3.00	3.17	4.50	9.17	8.67	5.50	8.67	5.83	7.33	9.50	8.83	7.33	8.00	8.83	7.33
T_5(Charisma)	2.50	3.50	3.50	2.50	3.33	4.17	6.83	7.50	8.00	7.50	6.17	8.17	7.33	6.67	9.50	7.50	8.33	7.67
T_6(Jadio)	2.00	3.00	3.17	3.67	3.00	4.83	7.67	7.33	6.17	7.33	5.33	7.33	8.00	6.67	7.83	7.17	7.50	5.00
T_7(Star Light)	3.17	3.67	4.83	3.33	4.50	5.50	6.50	8.83	7.17	8.83	5.83	5.17	6.50	6.67	4.83	6.83	6.33	3.33
T_8(Spray Orange)	3.00	2.67	2.17	1.83	2.67	3.50	5.00	5.50	3.50	5.50	3.50	5.17	5.67	5.33	7.83	5.83	6.83	4.50
T_9(Spray Yellow)	2.17	2.83	4.00	3.00	3.50	5.17	6.33	7.33	4.67	7.33	3.83	5.33	6.17	5.67	5.50	5.67	6.00	5.33
T_{10}(Red Varnish)	1.83	2.83	3.17	3.33	3.50	3.83	5.00	7.33	5.17	7.33	5.67	6.67	7.17	6.67	8.33	8.83	8.67	6.50
CD (5%)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**2.41**	**1.90**	**NS**	**NS**	**NS**	**NS**	**3.11**	**NS**	**NS**	**NS**
CV	**17.77**	**16.31**	**12.21**	**14.09**	**16.60**	**14.17**	**14.81**	**15.38**	**15.71**	**15.38**	12.28	**24.82**	**12.34**	**18.53**	**14.47**	**17.10**	**12.92**	14.92

Table 5. Number of leaves per branch of the loose flower varieties during 2017 September to 2018 May

Treatment	Months of observation																	
	September		October		November		December		Janauary		February		March		April		May	
	1st Fort night	2nd Fort night	1st Fort night	2nd Fort night	1st Fort night	2nd Fort night	1st Fort night	2nd Fort night	1st Fort night	2nd Fort night	1st Fort night	2nd Fort night	1st Fort night	2nd Fort night	1st Fort night	2nd Fort night	1st Fort night	2nd Fort night
T1(ArkaParimala)	20.83	26.67	37.33	28.67	37.33	28.67	17.00	25.33	17.00	25.33	22.83	19.83	23.67	19.67	19.50	20.00	18.83	17.67
T2(Sherba Gold)	29.50	30.00	32.33	33.33	32.33	33.33	20.33	31.67	20.33	31.67	26.67	7.67	15.17	18.83	9.50	6.83	6.83	7.50
T_3(Mirabel)	25.50	24.00	32.33	29.83	32.33	29.83	15.83	15.67	15.83	15.67	16.83	23.58	21.83	22.50	20.83	12.17	15.00	15.17
T_4(Vernish)	30.83	27.17	34.83	36.50	34.83	36.50	22.50	24.33	22.50	24.33	25.67	26.17	22.83	21.67	12.33	12.50	16.00	10.50
T_5(Charisma)	28.50	25.17	34.17	36.67	34.17	36.67	20.17	23.00	20.17	23.00	13.83	10.17	18.83	18.67	19.50	9.67	15.67	15.50
T_6(Jadiov)	23.17	23.50	35.83	30.67	35.83	30.67	16.50	19.67	16.50	19.67	18.50	16.17	12.17	19.00	13.83	10.83	9.83	10.67
T_7(Starlight)	23.33	30.83	38.67	29.33	38.67	29.33	33.83	37.17	33.83	37.17	10.00	11.83	17.67	14.00	17.33	14.50	10.17	8.83
T_8(Spray Orange)	23.67	32.67	27.67	27.33	27.67	27.33	21.83	34.83	21.83	34.83	20.83	24.42	19.00	24.17	13.67	15.17	19.00	20.33
T_9(Spray Yellow)	29.83	34.17	25.83	26.83	25.83	26.83	22.17	21.83	22.17	21.83	11.83	14.33	21.50	13.67	12.50	10.17	9.17	15.50
T_{10}(Red Varnish)	35.83	30.17	30.83	14.67	30.83	14.67	20.67	21.50	20.67	21.50	19.67	12.83	13.67	13.17	15.83	12.50	12.83	18.67
CD (5%)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**12.58**	**NS**	**12.58**	**NS**	**10.54**	**NS**	**NS**	**NS**	**6.69**	**NS**	**7.56**
CV	18.47	16.98	17.31	15.98	17.32	11.98	16.60	**15.98**	**16.60**	**17.95**	**16.63**	**16.05**	**13.04**	**16.61**	**16.10**	**14.35**	**13.58**	**11.60**

APPENDIX III

Monthly distribution of weather parameters during the experiment September 2017 to March 2018 (Outside poly house)

Parameters	September 2017	October 2017	November 2017	December 2017	January 2018	February 2018	March 2018
Mean Maximum Temperature (^{0} C)	31.5	31.7	33.0	32.4	33.5	35.7	36.7
Mean Minimum Temperature (^{0} C)	22.9	22.3	21.8	21.1	20.9	22.5	24.0
Mean Relative Humidity (%)	84.0	81.0	73.0	63.0	53.0	47.0	59.0
Rainfall (mm)	413.9	183.4	58.3	11.5	0.0	5.2	33.2
Rainy days	18.0	10.0	5.0	2.0	0.0	1.0	2.0
Mean Evaporation (mm)	2.8	2.3	3.0	3.9	4.4	5.6	5.0
Mean sunshine (hrs)	4.2	4.9	6.4	7.3	8.2	9.5	8.0
Mean Wind Speed (Km/Hr)	0.7	0.2	1.9	5.1	5.4	5.7	3.3

Monthly distribution of weather parameters during the experiment September 2017-March 2018 (Inside poly house)

Months	Temperature (^{0} C)	Relative humidity (%)	Photosynthetically active radiation (µmol $m^{-2}s^{-1}$)
September	30.00	60.25	200.55
October	31.66	64.21	266.91
November	32.75	57.12	585.88
December	31.5	51.99	685.36
January	31.96	41.64	535.00
February	34.00	32.53	504.87
March	32.07	50.23	134.05

EVLUATION OF ROSE VARIETIES FOR COMMERCIAL CULTIVATION UNDER THE WARM HUMID TROPICS OF KERALA

By

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ABSTRACT OF THE THESIS

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Abstract

An investigation entitled "Evaluation of rose varieties for commercial cultivation under the warm humid tropics of Kerala" was conducted in a naturally ventilated polyhouse of Department of Floriculture and Landscaping during August 2017 to March 2018. The objective of the study was evaluate the performance of cut flower and loose flower rose varieties under polyhouse and to select suitable varieties of both types for commercial cultivation in the plains of Kerala. Ten cut flower varieties *viz*. Arka Ivory, Arka Pride, Arka Swadesh, Gold Strike, Noblesse, Revival, Taj Mahal, Corvette, Emma, Peach Avalanche and ten loose flower varieties *viz*. Arka Parimala, Sherba Gold, Mirabel, Vernish, Charisma, Jadiov, Star Light, Spray Orange, Spray Yellow and Red Varnish were evaluated for vegetative as well as floral and genetic parameters.

The variety Taj Mahal was superior in plant height (52.83 cm) at peak flowering stage. Highest number of sprouts (2.83) was observed in variety Gold Strike whereas varieties Revival (5.5) and Peach Avalanche (5) had highest number of branches. Variety Arka Ivory (38.67) was found to have highest number of leaves at peak flowering stage.

Stalk length, bud size, number of petals per flower and keeping quality are the important quality criteria for cut flowers in National and International markets. The highest stalk length was observed in variety Emma (30.48 cm) and Arka Pride (31.35 cm) whereas variety Taj Mahal (79.1) was superior in terms of number of petals. Length and diameter of flower bud was superior in varieties Arka Ivory (2.77 cm and 1.09 cm) and Taj Mahal (2.53 cm and 1.21 cm). Longest vase life was observed in varieties Revival (4.83 days), Noblesse (4.75 days) and Taj Mahal (4.75 days). Highest number of marketable flowers was observed in varieties Arka Ivory (8.45), Taj Mahal (8.28) and Revival (7.23).

Among the loose flower varieties the variety Arka Parimala was superior with respect to plant height (59.82 cm) and number of branches (6.67). Variety

Charisma had highest number of sprouts (4) whereas variety Star Light was superior with respect to number of leaves per branch (44.47).

Varieties varied significantly with respect to floral characters. Highest number of petals was observed in variety Star Light (101) and variety Arka Parimala was found to have longest flower bud (2.6 cm), highest flower diameter (6.7 cm) and strong fragrance whereas this variety was inferior with respect to number of petals (15.4). Yield of marketable flowers was highest for the varieties Arka Parimala (34.33 g), Mirabel (20.83 g), Vernish (28.39 g), Charisma (28.7 g), Spray Orange (26.93 g) and Red Varnish (29.28 g). Variety Star Light was found to be superior in terms of overall performance.

The marketable flower yield over the months of observation indicated that November – December is the best season for rose production after the October pruning. High temperature and low humidity along with severe incidence of thrips reduced marketable yield during Feruary – March.

Dendrogram based on D^2 statistics indicated that there exists much diversity among the cut flower and loose flower varieties for both quantitative and qualitative characters.

The genetic estimates, GCV and PCV were found to be high for the characters *viz*. number of flowers per sprout (24.11 , 32.30), number of petals per flower (40.08, 43.56), yield of marketable flowers (27.71, 48.86) and fresh weight of the flower (21.19, 23.61) indicating wide variability for these characters among the ten cut flower varieties. The characters number of petals per flower (84.63,75.95), fresh weight of the flower (80.56, 39.18) and vase life (69.53, 26.96) exhibited high heritability coupled with high genetic advance indicating additive gene action in the expression of these characters and are highly inheritable while selection done based on these characters for cut flowers.

Among loose flowers, the genetic estimates GCV and PCV were found to be the highest for the characters number of flowers per sprout (42.25, 52.45), number of flowers per plant (26.93,34.43), number of petals per flower

(55.42,55.58), fresh weight of flower (61.69, 93.84), weight of petals per flower (83.81, 120.33) and flower diameter at fully opened stage (25.89, 28.71). High heritability coupled with high genetic advance were observed for the characters number of flowers per sprout (64.89,70.11), number of flowers per plant (61.19, 43.40), number of petals per flower (99.43, 50.12) and flower diameter at fully opened stage (81.32,48.10) indicating the existence of additive gene action and selection based on this characters will be effective.

Correlation and path analysis revealed that the characters *viz*. length of flower bud (1.041), number of flowers per plant (0.156) and number of petals per flower (1.045) were significantly and positively correlated with marketable yield per plant along with direct effect (1.131, 0.251, 0.285 respectively). Since, the characters number of flowers per plant and number of petals per flower had high GCV (%), PCV (%), high heritability (%) coupled with genetic gain (%) along with positive significant correlation and direct positive effect on marketable yield, these characters can be fixed as the selection criteria for loose flowers.