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High yielding nutmeg (*Myristica fragrans* Houtt.) varieties: a farmer-centric research approach to select superior trees

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Abstract

A comprehensive survey was conducted in the nutmeg-growing region of Kerala state to locate superior clones of nutmeg, by employing Participatory Varietal Selection (PVS) method. Twenty-nine superior accessions were identified through mother tree characterization for four consecutive years. The characterized clones were female and produced fruits ranging from 628 to 2250 tree^{-1} year^{-1}, dry nut weight varied from 3.27 g to 15.37 g, and assorted dry mace weight varied from 0.35 g to 4.80 g. Genetic variability analysis revealed high heritability with high genetic advance as per se mean (dry mace weight 76.30%, dry kernel weight 71.37% and the number of fruits tree^{-1} 73.24%) which signifies the advantage of simple selection method of breeding. Based on the economic importance of yield contributing characteristics, five superior clones out of twenty-nine mother trees evaluated have been released as KAU- farmer's varieties. All the superior trees identified based on yield traits had appreciable quantities of volatile oil (1.63-12.25% in nut; 3.31-16.97% in mace), oleoresin (17.60-41.77% in nut; 13.00-30.50% in mace) and fixed oil (22.45-40.70% in nut) in their nuts and maces as well as myristicin, elemicin, safrole and sabinene in the volatile oils. The characteristic features of mother trees and released varieties are discussed in this paper, and further, these varieties are recommended for commercial cultivation under tropical moist, humid climate conditions.

Keywords: Elite clones, *Myristica fragrans,* mother trees, participatory breeding, varieties

Introduction

Nutmeg (*Myristica fragrans* Houtt.) is a tree spice of dioecious sex form grown for its high-price fetching nut and mace. It originated from Moluccas Islands and was introduced into the Indian subcontinent by the British sailors during the 18th century. Now nutmeg is well adapted to climatic conditions of the Indian sub-continent exhibiting good performance, and the South Indian states *viz*. Kerala, Karnataka and Tamil Nadu dominate in the area as well as production of this crop (Anandaraj, 2015). The nature and extent of nutmeg's genetic variability have been nurtured in the moist humid tropics in the state of Kerala (Miniraj *et al.*, 2015; Vikram *et al.*, 2018). The cross-pollinating behaviour of the crop leads to the creation of variability in the seedling progenies (Haldankar *et al.*, 2013). The genetic variations are the first choice for describing and quantifying the germplasm used for selecting parental plants in a perennial tree crop like nutmeg (Vikram *et al.*, 2016a). The nature and extent of genetic variability studies are highly relevant to yield information that can be useful for crop improvement programmes (Marboh *et al.*, 2018).

The varieties suitable for commercial plantations have social and economic impacts on both the nutmeg growers as well as nursery men. Since the cultivable area of nutmeg in India has been steadily increasing, there is considerable demand for high-yielding varieties (Miniraj & Nybe, 2019). The complexity of nutmeg breeding is due to the perennial and dioecious nature of the crop, long juvenile periods to bear flowers and fruits and lack of methods to identify male and female plants at the seedling stage.

Previous studies on nutmeg have been concentrated on variability assessment, morphological and biochemical characterization and diversity analysis using molecular markers (Kusuma *et al.*, 2020; Anu *et al.*, 2019; Vikram *et al.*, 2017). These studies reveal that farmer's nutmeg plantations are characterized by germplasm richness. The presence of significant variation for morphological, biochemical, and yield traits of nutmeg in the farmer's plantations does help the breeder to plan a systematic crop improvement through the farmer's participatory breeding programme. Elite mother trees of nutmeg, can thus be identified, characterized and propagated through asexual means of budding or grafting by horticulturists (Miniraj & Nybe, 2019). Limited information is available about the custodians of such superior nutmeg clones in Kerala to attempt farmers' participatory breeding programme. At Kerala Agricultural University, a farmer centric approach has been developed to locate the custodian farmers who are in possession of high yielding nutmeg trees with superior quality fruits. The step-by-step procedure of this model along with the midterm and final output are presented in this paper.

Materials and methods

Identification of mother trees

Exclusive geographical location surveys were undertaken in the nutmeg growing regions to identify elite nutmeg trees in Kerala state, India. Participatory Varietal Selection (PVS) was employed in the study in order to identify the farmer acceptable nutmeg clones. On preliminary evaluation, twenty-nine high-yielding superior nutmeg mother trees were identified from different sites across the growing regions of Kerala state (Table 1). The custodian farmers were thoroughly interviewed to collect data on the performance of the identified clones. Five mother trees were evaluated per accession. Further, all economic traits of the selected mother trees were evaluated for four consecutive years from 2014 to 2107. All the selected mother trees were budded plants and pure female trees, which had come to stabilized bearing and were aged 12 to 15 years.

Table 1. The details of the nutmeg accessions and their altitude, longitude and latitude

Sl. No.	Accession number	Altitude (m)	Longitude	Latitude
1	Acc. 1	38	10°19'36.7"N	76°19'23.6"E
2	Acc. 2	36	10°20'05.6"N	76°23'07.4"E
3	Acc. 3	53	10°32'42.4"N	76°19'37.5"E
4	Acc. 4	36	10°20'05.6"N	76°23'07.4"E
5	Acc. 5	47	9°59'09.8"N	76°42'22.7"E
6	Acc. 6	36	10°20'05.6"N	76°23'07.4"E
7	Acc. 7	65	10°34'14.3"N	76°19'36.7"E
8	Acc. 8	65	10°34'14.3"N	76°19'36.7"E
9	Acc. 9	65	10°34'14.3"N	76°19'36.7"E
10	Acc. 10	65	10°34'14.3"N	76°19'36.7"E
11	Acc. 11	65	10°34'14.3"N	76°19'36.7"E
12	Acc. 12	446	10°30'13.3"N	76°28'45.9"E
13	Acc. 13	446	10°30'13.3"N	76°28'45.9"E
14	Acc. 14	30	9°46'56.4"N	76°24'43.7"E
15	Acc. 15	30	9°46'56.4"N	76°24'43.7"E
16	Acc. 16	47	10°18'56.5"N	76°23'44.4"E
17	Acc. 17	45	10°19'43.6"N	76°19'13.7"E
18	Acc. 20	48	9°40'40.8"N	76°34'01.3"E
19	Acc. 21	48	9°40'40.8"N	76°34'01.3"E
20	Acc. 22	74	11°22'47.5"N	76°20'18.9"E
21	Acc. 23	78	9°37'19.3"N	76°47'12.2"E
22	Acc. 24	44	10°31'56.9"N	76°18'35.1"E
23	Acc. 25	48	10°31'28.9"N	76°17'25.4"E
24	Acc. 26	67	10°17'39.3"N	76°27'23.8"E
25	Acc. 27	894	9°56'13.5"N	77°03'58.2"E
26	Acc. 28	894	9°56'13.5"N	77°03'58.2"E
27	Acc. 29	47	9°59'09.8"N	76°42'22.7"E
28	Acc. 30	36	10°20'05.6"N	76°23'07.4"E
29	Acc. 31	36	10°20'05.6"N	76°23'07.4"E

Morphological and biochemical observations

The morphological and biochemical analyses were done for the labeled twenty-nine mother trees in the farmer's field. A total of twenty morphological characters, including seven economically important yield parameters and thirteen differentiable qualitative characters, were recorded following standard guidelines. Qualitative characteristics and observation on the number of fruits square meter^{-1} and number of fruits tree^{-1} were recorded in the farm with the active participation of the farmer, and important fruit characteristics were recorded in the University laboratory. Observations / samples were taken from each quadrant from all the four sides of the tree. Twenty-five ripe split open fruits were collected for recording economic characters during the peak harvest period consecutively for four years from 2014 to 2017.

Biochemical studies

The dried kernel and mace (20 g per accession) collected from the selected mother trees were ground for the extraction of volatile oil (Clevenger's method), oleoresin (ASTA method) and fixed oil (AOAC method) using standard procedures. The volatile oil, oleoresin and fixed oil content per tree were calculated and expressed in percentages.

The volatile oil thus isolated was treated with a pinch of anhydrous sodium sulphate to remove moisture and then stored in the refrigerator (4 ^{o}C) for further chemical profiling. GCMS analysis of kernel and mace volatile oils of select seven elite accessions was done using Shimadzu GC QP-2010 attached to RtX-5, 30 m × 0.32 mm × 0.25 μm capillary column coupled with a QP-2010 mass detector. GCMS operation conditions were split ratio of 1:40, injector temperature at 240 ^{o}C, interspaces at 240 ^{o}C, detector temperature of 240 ^{o}C, carrier gas used as helium with a linear velocity of 48.1 cm per second with the split ratio at 50. The mass spectra were electron impact mode 70 eV with an ion source of 200 ^{o}C. The individual chemical constituents of volatile oil were identified by comparing the mass fragment pattern with the standard spectra of the database.

Statistical analysis of data

The observations on yield parameters and biochemical analysis were recorded in replicated values. One way analysis of variance (ANOVA) was carried out to compare the mean values of fresh and dry weight of mace and nut, number of fruits square meter^{-1}, number of fruits tree^{-1} and biochemical traits such as volatile oil, oleoresin and fixed oil content of different nutmeg accessions using SPSS 16.0 at $p \leq 0.05$. The method employed to distinguish among means of economic and biochemical parameters was Duncan's test (Multiple Range Test). Further, the accessions were ranked high and low based on the significance values. Since a range of overlapping sub groups were obtained within the parameters, the method followed to make decisions jointly on a number of dependent characters as proposed by Arunachalam & Bandyopadhyay (1984) was co-opted. The final rank derived is an indicator of the relative superiority of the accessions in terms of the yield and yield contributing parameters of nutmeg tree. For understanding the factors contribution to the variability, descriptive statistics *viz.* mean, range, phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability broad sense (H^2) and genetic advance as per se mean (%) was then worked out for the seven economical yield parameters using SPSS 16.0.

Results and discussion

Evaluation of mother trees

The selected accessions were preliminarily assessed for fruit parameters and yield traits during the peak fruiting season. The select accessions exhibited significantly high values for yield and other economic characters (Table 2). Fresh mace weight among the accessions ranged from 0.99 to 6.30 g. Dry mace weight ranged from 0.35 to 4.80 g. Significantly highest fresh and dry weights of mace was recorded in Acc. 28 (6.30 g and 4.80 g, respectively). The accession that recorded the highest fresh and dry mace weights was an unique seedless morphotype with rather rudimentary or no seed inside the mace. Though the accession had thick and multilayer folded compact mace, the nut was not properly developed. Single fresh nut weight was significantly highest in Acc. 27 (21.0 g) whereas dry nut weight was significantly highest in Acc. 26 (15.37 g), which was followed by Acc. 27 (13.78 g). However, after shelling, the kernel weight was significantly highest in Acc. 27 (9.57 g) and lowest in Acc. 24 (2.10 g). Mace, nut and kernel weights are the critical economic parameters that could decide the superiority of nutmeg accessions. The accessions possessed heavier mace and nut than that measured under high rainfall and high-altitude Kodagu region of Karnataka as reported by Senthilkumar *et al.* (2010). The present study materials had superior nut and mace characters when compared to the wide variation noticed among the accessions of a core nutmeg collection at the Chalakudy river basin of central Kerala (Vikram *et al.*, 2016). Variation in fruit weight is mainly a genotypic character even though pedo-climatic conditions may also play a role (Khadivi-Khub & Ebrahimi, 2015). Nut and mace weights are essential traits that directly contribute to the yield and attract high value in the market. In the present study, the number of fruits square meter^{-1} was significantly highest in Acc. 4 (46.00), followed by Acc. 26 (39.40) and Acc. 3 (39.00). About seven accessions recorded 31.0 to 33.0 fruits square meter^{-1}. Ten mother trees among twenty-nine produced more than 30 fruit square meter^{-1}. In perennial trees like nutmeg, the number of fruits produced per unit area is an essential factor that directly influences yield. The number of fruits tree^{-1} varied widely from 628 to 2250. These differences may be due to the genotypic influence and the growing environment conditions. There are few studies which differentially reported the number of fruit tree^{-1}; Shinde *et al.* (2006) observed eight to ten-year-old nutmeg tree producing only 20 to 80 fruits tree^{-1} under Dapoli conditions. Senthilkumar *et al.* (2010) reported considerable variation in the number of fruits tree^{-1} (12 to 1759) from twenty-five-year-old trees from high rainfall and high-altitude ranges of Kodagu district of Karnataka.

Table 2. Yield, mace and nut parameters of nutmeg accessions

Sl. No.	Accession	Fresh mace Weight (g)	Dry mace weight (g)	Fresh nut weight (g)	Dry nut weight (g)	Kernel weight (g)	No. of fruits m^{-2}	No. of fruits tree m^{-2}	Ranking
1	Acc. 1	3.49^{i}	1.36^{jklmn}	14.66^{e}	10.81^{def}	7.30^{f}	33.00^{cd}	2120^{bcd}	7
2	Acc. 2	2.13^{l}	0.95^{n}	10.09^{lm}	7.35^{ijk}	5.50^{k}	27.00^{efgh}	1950^{cd}	25
3	Acc. 3	2.71^{j}	1.70^{ghijkl}	11.47^{k}	9.80^{fg}	5.30^{lm}	39.00^{b}	1450^{g}	14
4	Acc. 4	3.91^{gh}	1.02^{mn}	12.77^{ghi}	8.01^{ij}	5.43^{kl}	46.00^{a}	1700^{efg}	12
5	Acc. 5	4.67^{cd}	2.43^{cde}	14.50^{e}	11.60^{cd}	7.64^{d}	33.00^{cd}	1800^{def}	3
6	Acc. 6	2.85^{j}	1.22^{klmn}	13.14^{g}	8.01^{ij}	5.78^{j}	10.00^{k}	1000^{h}	24
7	Acc. 7	4.73^{c}	1.81^{fghijk}	9.38^{no}	6.37^{k}	4.89^{no}	26.00^{fghi}	2010^{bcd}	16
8	Acc. 8	3.95^{g}	1.63^{hijklm}	12.32^{hij}	8.20^{ij}	5.21^{m}	33.00^{cd}	2180^{ab}	8
9	Acc. 9	3.75^{gh}	1.69^{ghijkl}	10.00^{lm}	6.40^{k}	5.00^{n}	27.20^{efgh}	2250^{b}	19
10	Acc. 10	3.75^{gh}	1.62^{hijklm}	11.38^{k}	8.72^{ghi}	4.65^{p}	24.00^{ghi}	2250^{a}	17
11	Acc. 11	4.40^{ef}	2.00^{defghi}	10.51^{l}	6.44^{k}	3.90^{r}	22.00^{ij}	1950^{cd}	20
12	Acc. 12	4.83^{c}	2.41c^{def}	14.33^{e}	9.87^{fg}	7.46^{e}	33.00^{cd}	1500^{fg}	6
13	Acc. 13	3.94^{gh}	2.48^{bcd}	14.38^{e}	12.64^{bc}	8.63^{b}	31.00^{cde}	1558^{fg}	4
14	Acc. 14	4.20^{f}	2.29^{cdef}	14.70^{e}	10.05^{ef}	6.80^{g}	33.00^{cd}	2200^{ab}	5
15	Acc. 15	4.52^{de}	2.29^{cdef}	9.34^{op}	7.00^{jk}	4.88^{no}	24.00^{ghi}	1875^{cd}	21
16	Acc. 16	3.29^{i}	1.43^{ijklmn}	16.01^{d}	8.33^{hij}	5.34^{lm}	24.00^{ghi}	1980^{h}	18
17	Acc. 17	2.22^{kl}	1.30^{jklmn}	13.70^{f}	11.24^{de}	6.6^{j}	28.00^{efg}	1925^{cd}	10
18	Acc. 20	5.31^{b}	1.85^{fghijk}	9.86^{mn}	6.95^{jk}	4.42^{q}	24.00^{ghi}	9850^{h}	23
19	Acc. 21	3.35^{i}	2.40^{cde}	11.91^{jk}	6.35^{k}	4.80^{o}	22.83^{hij}	8916^{h}	22
20	Acc. 22	2.71^{j}	1.25^{klmn}	12.16^{ij}	9.54^{fgh}	4.50^{q}	22.20^{ij}	1670^{fg}	27
21	Acc. 23	2.37^{k}	1.85^{fghijk}	8.73^{p}	7.15^{jk}	4.36^{q}	19.60^{j}	2010^{bcd}	28
22	Acc. 24	2.76^{j}	0.35^{o}	6.78^{q}	3.27^{l}	2.10^{s}	29.00^{def}	1375^{g}	29
23	Acc. 25	0.99^{n}	2.16^{cdefg}	12.71^{ghi}	7.96^{ij}	5.428^{kl}	34.00^{c}	628^{j}	15
24	Acc. 26	5.27^{b}	2.16^{cdefg}	17.59^{b}	15.37^{a}	8.16^{e}	39.40^{b}	630^{j}	2
25	Acc. 27	4.49^{de}	3.01^{b}	21.00^{a}	13.78^{b}	9.57^{a}	27.40^{efg}	690^{ij}	1
26	Acc. 28	6.30^{a}	4.8^{a}	0^{r}	0^{m}	0^{t}	25.80^{fghi}	850^{ij}	26
27	Acc. 29	1.88^{m}	1.91^{efghij}	12.68^{ghi}	8.70^{ghi}	5.92^{ij}	27.80^{efg}	995^{h}	13
28	Acc. 30	3.72^{h}	2.57^{bc}	17.01^{c}	6.44^{k}	6.0^{i}	19.60^{j}	1380^{g}	8
29	Acc. 31	4.37^{ef}	1.16^{lmn}	12.81^{gh}	10.76^{def}	7.70^{d}	25.25^{fghi}	1991^{bcd}	9

Values not sharing a common superscript in the row differ significantly with each other ($P < 0.05$).

Nutmeg trees produce two distinct products: the mace and the nut and hence choosing an ideal tree for both mace and nut characters is often difficult. In a detailed study on the characterization and evaluation of nutmeg accessions, Vikram *et al.* (2016a) have developed a statistical tool using 13 key quantitative characters to identify an elite nutmeg tree. Number of fruits square meter^{-1} (19), dry mace weight (2 g), dry nut weight (10 g) and kernel weight (7 g) are the minimum values prescribed by them to classify a nutmeg tree as an elite type. Comparing these values, it is evident that in the present study, more than 50 per cent of the accessions evaluated belonged to the ideal tree type. Further, Miniraj *et al.* (2015a) have opinioned that to designate as a plus tree; it should possess a minimum of 2 g of dry mace weight, 10 g of dry nut weight and produce around 2000-3000 fruits tree^{-1} year^{-1}. Considering the four crucial economic traits needed for a superior tree of nutmeg, seven accessions in the study were shortlisted out of the total twenty-nine. The designated superior accessions were Acc. 1, Acc. 5, Acc. 12, Acc. 13, Acc. 14, Acc. 26 and Acc. 27. These seven accessions could very well be categorized as elite nutmeg genotypes producing more fruits with excellent dry weights of mace, nut and kernel.

Biochemical characterization

The principal quality attributes of nutmeg and mace are volatile oil, oleoresin and fixed oil. The percentages of nut and mace constituents differed between the accessions (Table 3). The volatile oil content in nut ranged from 1.63 to 12.25 per cent, and that in mace from 3.31 to 16.97 per cent. Significantly highest nut volatile oil was recorded in Acc. 12, which is also categorized as a superior clone. Seedless clone (Acc. 28) had significantly highest mace oil content which also possessed appreciable quantities mace thereby ensuring quality with mace yield. The oleoresin content of accessions ranged from 17.60 to 41.77 per cent in nut and 13.00 to 30.50 per cent in mace. Fixed oil in the nut was to the tune of 22.45 to 40.74 per cent. It is often difficult to combine quantity and quality in the same genotype. Out of seven elite accessions selected based on a good record of economic characters; Acc. 1, Acc. 5, Acc. 12, Acc. 13 and Acc. 26 possessed good mace oil, mace oleoresin and fixed oil. Acc. 14 and Acc. 27 were categorized as medium-quality types. The biochemical constituents of the accessions studied exhibited higher values than that of a previous study by Abdurrasheed & Janardanan (2009) and Vikram *et al.* (2022). It is evident that the major constituents of nutmeg volatile oil *viz.* myristicin, elemicin, safrole and sabinene, were present in elite accessions in appreciable quantities (Table 4). The content of myristicin ranged between 0.73 to 11.39 per cent in mace oil and from 1.05 to 8.40 per cent in kernel oil. Elemicin content ranged from 0.36 to 8.65 per cent in mace oil and from 0.48 to 12.25 per cent in kernel oil. Safrole (0.13 to 8.49 % in nuts and 0.19 to 5.72 % in mace oil) was also detected in all the accessions. Chirathaworn *et al.* (2007) identified myristicin, eugenol, isoeugenol and elemecin as the major bioactive compounds in nutmeg oil. Kapoor *et al.* (2013) detected sabinene (29.40%) as the primary component, along with beta-pinene (10.60%), alpha-pinene (10.10%) and terpenen-4-ol (9.6%). Sabinine, which imparts sweetness to the oil, was also recorded in higher quantities in all the elite accessions. Krishnamoorthy *et al.* (2014) have also reported a sabinene rich nutmeg accession, (35.40 per cent in nut oil and 29.40 per cent in mace oil). Sabinene content of the accessions in the present study ranged from

21.67 to 30.80 per cent in mace oil and 24.13 to 38.39 per cent in nut oil. Variation in constituents could be due to the growing environment, time of harvest, method of extraction and genetic makeup of the accessions as reported by Leela (2008). However, with respect to the major constituents, all the superior trees identified based on yield traits had higher quantities of the respective constituent.

Table 3. Volatile oil, oleoresin and fixed oil content of nutmeg accessions

Sl. No.	Accession	Volatile oil (%)		Oleoresin (%)		Fixed oil (%)
		Kernel	Mace	Kernel	Mace	
1	Acc. 1	4.60^{j}	12.03^{c}	31.75^{fg}	25.25^{d}	34.64^{b}
2	Acc. 2	7.30^{c}	8.7^{k}	27.55^{k}	18.65^{m}	27.76^{m}
3	Acc. 3	5.84^{h}	7.84^{n}	17.60^{q}	22.75^{h}	28.60^{k}
4	Acc. 4	1.63^{o}	8.13^{m}	17.67^{q}	25.22^{d}	24.71^{r}
5	Acc. 5	6.90^{d}	11.00^{e}	24.90^{n}	28.65^{b}	31.60^{e}
6	Acc. 6	5.05^{j}	8.63^{k}	26.10^{m}	22.35^{i}	40.74^{a}
7	Acc. 7	3.40^{l}	7.05^{q}	25.95^{m}	28.65^{b}	29.75^{j}
8	Acc. 8	5.20^{j}	7.25^{p}	22.70^{mn}	17.65^{o}	27.76^{m}
9	Acc. 9	3.59^{l}	6.58^{r}	21.15^{p}	17.55^{o}	24.25^{s}
10	Acc. 10	5.17^{j}	12.76^{b}	26.15^{m}	22.10^{i}	22.52^{u}
11	Acc. 11	2.66^{n}	4.05^{u}	30.30^{h}	24.90^{e}	31.07^{fg}
12	Acc. 12	12.25^{a}	7.33^{p}	39.30^{b}	17.60^{o}	23.64^{t}
13	Acc. 13	6.05^{gh}	10.66^{g}	41.77^{a}	22.49^{g}	22.66^{u}
14	Acc. 14	6.13^{g}	9.05^{i}	31.75^{fg}	14.35^{r}	25.06^{q}
15	Acc. 15	5.94^{gh}	8.29^{m}	30.35^{h}	18.85^{m}	25.87^{p}
16	Acc. 16	5.49^{i}	8.36^{lm}	27.00^{kl}	21.70^{j}	30.89^{gh}
17	Acc. 17	7.10^{cd}	11.73^{d}	25.60^{mn}	22.32^{i}	32.17^{d}
18	Acc. 20	7.66^{b}	9.00^{i}	25.60^{mn}	19.55^{l}	31.25^{f}
19	Acc. 21	6.67^{e}	5.36^{t}	31.85^{f}	24.05^{f}	30.25^{f}
20	Acc. 22	3.10^{m}	9.00^{i}	32.45^{f}	16.45^{p}	29.51^{j}
21	Acc. 23	5.86^{h}	8.83^{j}	32.10^{f}	27.70^{c}	30.89^{h}
22	Acc. 24	6.39^{f}	5.68^{s}	28.60^{j}	22.32^{i}	26.65^{no}
23	Acc. 25	5.00^{j}	7.63^{o}	23.45^{o}	13.00^{s}	25.75^{p}
24	Acc. 26	6.10^{g}	3.31^{v}	33.45^{e}	20.10^{k}	34.10^{c}
25	Acc. 27	4.55^{k}	9.55^{h}	29.40^{i}	18.00^{n}	28.13^{l}
26	Acc. 28	0^{p}	16.97^{a}	0^{r}	27.65^{c}	0^{v}
27	Acc. 29	5.49^{i}	8.45^{l}	35.62^{d}	23.45^{g}	24.87^{qr}
28	Acc. 30	6.60^{e}	10.84^{f}	26.25^{lm}	15.75^{q}	26.46^{o}
29	Acc. 31	4.64^{k}	9.55^{h}	37.62^{c}	30.50^{a}	22.45^{u}

Values not sharing a common superscript in the row differ significantly with each other ($P < 0.05$).

Table 4. Constituents (%) of volatile oil of nutmeg accessions

Sl. No	Accessions	Mace oil				Kernel oil			
		Myristicin	Elemicin	Safrole	Sabinene	Myristicin	Elemicin	Safrole	Sabinene
1	Acc. 1	0.73	6.93	0.52	29.90	1.05	5.62	0.19	30.61
2	Acc. 5	6.90	5.62	3.88	30.80	6.82	4.23	3.94	30.81
3	Acc. 12	9.12	8.65	1.78	27.27	8.40	9.74	1.80	30.09
4	Acc. 13	2.37	0.49	0.13	28.58	3.83	0.48	0.19	38.39
5	Acc. 14	1.49	0.36	4.06	21.67	5.19	1.39	5.72	24.13
6	Acc. 26	11.39	5.93	1.68	25.43	2.85	1.81	1.37	27.70
7	Acc. 27	13.27	5.88	8.49	22.94	7.42	12.25	2.88	32.14

Assessment of variability

The descriptive statistics were studied for seven characters in twenty-nine nutmeg accessions (Table 5). The genotypic coefficient of variation was the highest for dry mace weight (37.06 %), followed by the number of fruits tree^{-1} and dry nut weight. High genotypic as well as phenotypic coefficients of variation were observed for all the characters. The economic parameters such as dry nut weight, dry mace weight, and the number of fruits tree^{-1} showed high computed values for both genotypic and phenotypic coefficients of variation. The accessions evaluated also exhibited high heritability for all the characters. High genotypic coefficient of variation and high heritability in the characters points to the scope for yield improvement through selection based on economic yield traits. Genetic advance as per se mean was the highest for dry mace weight (76.30 %) that was followed by the number of fruits tree^{-1} (73.24%) and kernel weight (71.37 %). These findings suggest that selection programme in nutmeg can be based on dry mace weight, dry nut weight, kernel weight and the number of fruits tree^{-1} to improve the base population. Vikram *et al.* (2016) have also reported that number of fruits tree^{-1}, fresh weight of mace, dry weight of mace and volume of nut are the essential parameters to be considered in nutmeg selection programme.

Table 5. Descriptive statistics for yield contributing characters in nutmeg

Character	Range	Mean	GCV (%)	PCV (%)	Heritability (%)	Genetic advance as per se mean (%)
Fresh nut weight (g)	6.78- 21.0	12.22	30.76	31.29	96.62	62.28
Dry nut weight (g)	3.27- 15.37	8.49	35.23	38.09	85.56	67.14
Kernel weight (g)	2.10 – 9.57	5.63	34.69	34.73	99.76	71.37
Fresh mace weight (g)	0.99 - 6.30	3.66	32.17	32.76	96.45	65.09
Dry mace weight (g)	0.35 – 4.80	1.86	37.06	37.09	99.86	76.30
Number of fruits/m^2	19.60-46.00	27.86	26.16	26.82	95.11	52.56
Number of fruits/tree	628- 2250	1528.32	36.11	36.68	96.91	73.24

*PCV & GCV (Sivasubramanian & Madhavamenon 1973) – Low=less than 10%; Moderate=10-20%; High=more than 20%

*H^2 (Johnson *et al*., 1995) – Low=less than 30%; Moderate=30-60%; High=more than 60%

*GG (Johnson *et al*., 1955) – Low=less than 10%; Moderate=10-20%; High=more than 20%

Elite clones for commercial cultivation

Evaluation of nutmeg mother trees for four consecutive years in the farmer's field for productivity and quality, resulted in the identification of seven elite nutmeg clones possessing the highest values for characteristics like dry nut weight, dry mace weight and the number of fruits tree^{-1}. The studied accessions were also significantly superior for dry nut and mace weights and number of fruits tree^{-1} when compared to IISR Vishwashree (9.08 g dry nut weight, 1.30 g dry mace weight and 1448 number of fruit tree^{-1} as reported by Mathew *et al.*, 2016), which is considered as national check variety in nutmeg. These mother trees also possessed medium to high-quality oil, oleoresin and fixed oil as well as volatile oil constituent's *viz*. myristicin, elemicin, safrole and sabinene. High intrinsic quality is another essential characteristic demanded by the pharmaceutical and food industries. However, combining all the desirable characteristics into a single variety is difficult in perennial crops like nutmeg, which is also unique with its dioecious nature, high heterozygosity, polygenic traits and a long juvenile period (Sasikumar, 2009). Five among these select elite nutmeg accessions have been released as KAU-farmer varieties and recommended for commercial cultivation in areas receiving tropical moist humid climates. The varieties are KAU-Pullan (Acc. 1), KAU-Kochukudy (Acc. 5), KAU-Mundathanam (Acc. 12), KAU-Poothara (Acc. 14) and KAU-Punnathanam (Acc. 27). The salient features of these released varieties are furnished in Table 6. All the varieties have been registered with PPV&FRA, New Delhi and the onsite DUS testing was done by

PPV&FRA, Regional Centre, KKVV, Dapoli, Maharashtra. Further, this is a classic example of the effectiveness of Participatory Varietal Selection (PVS) to identify varieties with the active involvement of farmers who have identified the variety and thereafter, by ascertaining their claims through rigorous scientific testing. It is also a rapid and cost-effective way of evolving elite cultivars or varieties in a perennial crop like nutmeg with its inherent breeding challenges.

Table 6. Salient features of released nutmeg varieties

SL. No.	Character	KAU-Pullan (Acc. 1)	KAU-Kochukudy (Acc. 5)	KAU-Mundathanam (Acc. 12)	KAU-Poothara (Acc. 14)	KAU-Punnathanam (Acc. 27)
1	Canopy shape	Conical	Conical	Pyramidal	Pyramidal	Broadly pyramidal
2	Branching pattern	Erect	Spreading	Erect	Spreading	Erect
3	Leaf shape (mature)	Elliptic	Lanceolate	Elliptic	Elliptic	Oblong
4	Leaf colour (mature)	Dark green	Dark green	Green	Dark green	Dark green
5	Fruit colour (mature)	Yellow	Yellow	Yellow	Yellow	Yellow
6	Fruit shape(whole)	Spherical	Round	Oval	Round	Round
7	Mace shape	Oval	Round	Round	Round	Oblong
8	Nut shape	Oval	Round	Round	Round	Oblong
9	Mace colour (fresh)	Dark red	Dark red	Dark red	Dark red	Red
10	Mace colour (dry)	Red	Dark red	Red	Red	Scarlet red
11	Nut colour (fresh)	Brownish black	Brownish black	Brownish black	Brownish black	Brownish black
12	Nut colour (dry)	Black	Black	Dark brown	Black	Dark brown
13	Thickness of pericarp (fresh)	9.82 mm	10.94 mm	12.96 mm	11.0 mm	21.1 mm

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