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RESEARCH ARTICLE

Variability and Yield Contributing Principal Components in Nutmeg (*Myristica fragrans* Houtt.)

HC Vikram[1*†], N Miniraj[1] and Deepu Mathew[2]

[1] *Department of Plantation Crops and Spices, College of Horticulture, Kerala Agricultural University, Thrissur – 680656, Kerala, India.*

[2] *Centre for Plant Biotechnology and Molecular Biology, College of Horticulture, Kerala Agricultural University, Thrissur – 680656, Kerala, India.*

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In nutmeg, fruit weight, mace volume and pericarp thickness have direct and kernel volume, mace dry weight and fruit set have indirect effects on yield. Selection for higher yield should be based on most contributing principal component fruits/tree, followed by plant girth, canopy spread, flowers/10cm^2, fruit set and fruit weight.

Key Words: Core collections, Genetic variability, *Myristica fragrans*, Path analysis, Principal components

The nutmeg tree (*Myristica fragrans* Houtt.) is source of two distinct spices; namely nutmeg and mace, valued highly for flavouring and medicinal properties. The crop native to Moluccas, Indonesia, is presently cultivated in India and many other tropical countries. High amount of variability has been reported throughout the nutmeg growing tracts of India with respect to the growth rate and flushing pattern (Nazeem, 1979), productivity, size and shape of the leaf, flower size and shape of the fruit and nut (Senthilkumar *et al.*, 2010; Miniraj *et al.*, 2015b). The crop improvement studies carried out in the nutmeg growing regions in India have given special emphasis on yield maximization. A tree producing 3000 fruits per year along with other economic characters is considered as high yielder (Miniraj *et al.,* 2015a). Inheritance of most of the economic traits is complex in nutmeg and mainly involves fruit and tree characteristics. The path coefficient method is an important tool for revealing the true nature of effect-cause interrelations between yield and its primary components. PCA is an exploratory tool designed by Karl (1901) to identify unknown trends in a multi-dimensional data set. In the past, there has been no attempt to use path-coefficient and principal component analysis to study the yield traits in nutmeg. The present study was undertaken to determine a classificatory analysis on the yield components of nutmeg core collections from diverse locations of Kerala, India by means of analysing the variability and partitioning it into direct and indirect effects by path and principal component analyses. This would enable us to classify the available morphotypes into distinct groups on the basis of their genetic diversity.

The study was carried out at Kerala Agricultural University, Thrissur during 2012-15. Core collections represented all the nutmeg growing regions of Kerala and planted in Chalakudy river basin central parts of Kerala (latitude 10.33ºN, longitude 76.33ºE), formed the material for study. Among the forty six selected accessions, forty two were females and four monoecious with same age group of fifteen years as per farmers registers. In each accession, observations were recorded from two trees per accession during two consecutive bearing seasons.

Following Completely Randomised Design (CRD), analysis of variance was done primarily for each of the 38 quantitative traits. Among them, 26 traits were selected based on their contribution to yield, statistical significance and economic importance. The analyses on variability, path coefficient and principal components were performed based on these 26 traits. The computer package SPSS v.16 (SPSS, 2007) was used for the analyses.

The accessions in the present study showed a wide range of variation for yield attributes (Table 1) *viz*.,

* *Author for Correspondence: Email- vikram.hc@gmail.com*
† *Present address: Division of Fruit Crops, Indian Institute of Horticultural Research, Hesaraghatta Lake Post, Bangalore–560089, Karnataka, India.*

Table 1. Variability in nutmeg morphotypes for yield contributing traits

Characters	Mean	Minimum	Maximum	CV (%)	Skewness	Kurtosis
Plant height (m)	7.79	3.20	12.35	4.53	0.24	0.73
Plant girth (cm)	44.77	20.33	63.51	5.54	-0.41	-0.09
Canopy spread (E-W)-(m)	5.80	3.11	9.03	8.51	0.50	0.12
Canopy spread (N-S)-(m)	5.77	3.13	8.85	6.54	0.30	0.02
Leaf area (cm^2)	33.94	20.29	54.63	10.45	0.53	0.88
No. of flowers/10cm^2	5.11	2.50	10.25	15.24	1.36	3.96
Fruit set percentage	22.96	6.15	44.15	5.29	0.05	-1.09
No. of fruits/m^2	14.66	2.75	31.50	18.59	0.44	-0.25
Fruit weight (g)	64.35	39.33	99.57	3.73	0.46	-0.28
Fruit length (mm)	57.55	42.15	66.25	2.18	-0.69	0.23
Fruit breadth (mm)	48.85	35.19	57.44	2.18	-0.68	0.39
Thickness of pericarp (mm)	11.94	8.26	15.70	6.21	0.16	-0.23
Fresh mace weight (g)	2.25	0.91	5.27	13.83	1.44	4.80
Dry mace weight (g)	1.12	0.46	2.62	13.47	1.32	2.72
Fresh nut weight (g)	10.01	4.42	13.67	8.74	-0.14	0.05
Dry nut weight (g)	7.07	3.56	11.01	6.93	0.27	0.14
Shell thickness (mm)	1.04	0.80	1.42	5.77	0.57	1.71
Kernel weight (g)	5.20	2.65	8.05	10.49	0.23	-0.49
Fruit volume (cm^3)	57.46	21.95	89.37	9.96	-0.32	1.74
Nut volume (cm^3)	9.49	4.00	13.21	6.18	-0.51	0.15
Mace volume (cm^3)	2.54	1.00	4.73	17.32	0.23	-0.71
Kernel volume (cm^3)	5.72	2.00	8.23	11.35	-0.64	0.80
Nut length (mm)	31.22	22.17	36.64	3.22	-0.54	-0.10
Nut breadth (mm)	23.99	16.88	34.72	2.45	0.23	3.33
Ratio of nut to mace	4.94	2.06	9.69	9.12	0.83	089
No. of fruits/tree	1398.09	27	4420	22.16	0.90	0.02

number of fruits/tree (22.16%), mace volume (17.32%), fresh mace weight (13.83%), dry mace weight (13.47%), kernel volume (11.35%) and kernel weight (10.49%), number of fruits/m^2 (18.59%), number of flowers/10cm^2 (15.24%) as well as leaf area (10.45%). The variation ranged from 27 to 4420 for number of fruits/tree, 1.0 to 4.73 cm^3 for mace volume, 0.91 to 5.27 g for fresh mace weight, 0.46 to 2.62 for dry mace weight, 2.0 to 8.23 cm^3 for kernel volume, 2.65 to 8.05 g for kernel weight, 2.75 to 31.50 for number of fruits/m^2, 2.50 to 10.25 for number of flowers/10cm^2 and 20.29 to 54.63 cm^2 for leaf area. The variability noticed in the fruit characters was ultimately reflected in the nutmeg yield. Senthilkumar *et al.* (2010) also reported wide range of variability in fruit characters of nutmeg under high altitude areas of Karnataka.

Significant skewness and kurtosis clearly exhibits normality of the distribution. It could be noted that majority of characters possessed positively skewed distribution and were controlled by additive gene action with complementary epistasis. The traits *viz*., plant girth, fruit length, fruit breadth, fresh nut weight, fruit volume, nut volume, kernel volume and nut length showed additive gene action with duplicate epistasis. Hence, if we go in selection programme based on these characters, we can bring improvement over base population. Similarly, majority of the characters possessed leptokurtic (positive) graphic distribution and were controlled by little genes (genes showing antagonistic affect on each other). Characters such as plant girth, fruit set percentage, number of fruits/m^2, fruit weight, thickness of pericarp, kernel weight, mace volume and nut length have shown platykurtic (negative) graphic distribution and were under the influence of many genes (genes showing synergetic affect each other). For all the genetic parameters, prediction of gene action was made as per suggestion given by Roy (2000). Similar results were reported by Shobha *et al.* (2013) in cashew.

Among the traits subjected to path analysis, fourteen traits showed positive direct effects on number of fruits per tree (Table 2). The pertinent data revealed that fruit weight (2.04), mace volume (1.98) and thickness of pericarp (1.29) exerted very high genotypic positive direct effect on number of fruits per tree and very high

Table 2. Path co-efficient analysis of nutmeg accessions for yield contributing characters

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	**22**	**23**	**24**	**25**	**rG**
1	**-0.23**	-0.01	-0.42	0.22	-0.10	-0.03	0.1	0.01	0.12	0.10	-0.21	0.45	0.40	-0.03	0.003	0.10	-0.01	-0.10	-0.09	0.48	-0.13	-0.23	-0.05	-0.003	0.0005	0.26
2	-0.13	**-0.02**	-0.43	0.23	-0.10	-0.043	0.023	0.004	0.46	-0.04	-0.25	0.58	0.10	0.09	0.002	-0.005	0.01	0.07	-0.35	0.12	-0.11	-0.03	-0.04	0.008	-0.001	0.16
3	-0.12	-0.01	**-0.81**	0.40	-0.09	0.098	0.20	0.013	0.53	0.02	-0.34	0.64	-0.53	0.25	-0.0003	-0.10	0.11	0.12	-0.35	0.016	0.23	0.04	-0.05	0.12	-0.005	0.38
4	-0.12	-0.01	-0.75	**0.42**	-0.09	0.10	0.15	0.005	0.43	0.02	-0.31	0.63	-0.61	0.29	-0.0003	-0.10	0.11	0.13	-0.31	-0.025	0.27	0.03	-0.02	0.10	-0.0060	0.34
5	-0.09	-0.01	-0.29	0.15	**-0.25**	0.01	-0.001	0.004	0.23	0.13	-0.12	0.39	0.29	-0.03	0.003	0.17	0.01	-0.17	-0.23	0.55	-0.26	-0.24	-0.10	-0.07	0.0002	0.07
6	0.01	0.002	-0.17	0.09	-0.01	**0.45**	-0.17	-0.01	0.18	-0.03	-0.09	0.15	-0.47	0.02	0.001	0.08	0.06	-0.09	-0.15	0.008	0.09	-0.07	-0.02	0.02	-0.005	-0.11
7	-0.02	-0.001	-0.19	0.08	0.0004	-0.10	**0.82**	0.054	0.53	-0.24	-0.24	0.31	-0.57	0.21	-0.01	-0.26	-0.01	0.37	-0.21	-0.90	0.23	0.37	0.18	0.19	0.005	0.62
8	-0.03	-0.001	-0.16	0.03	-0.014	-0.09	0.69	**0.064**	0.47	-0.16	-0.23	0.34	-0.005	-0.013	-0.004	-0.14	-0.01	0.23	-0.16	-0.70	0.10	0.23	0.09	0.18	0.008	0.72
9	-0.01	-0.004	-0.21	0.09	-0.03	0.04	0.21	0.01	**2.04**	-0.47	-0.72	1.16	-1.28	0.32	-0.01	-0.29	0.12	0.35	-1.69	-1.52	1.04	0.59	0.19	0.31	-0.003	0.27
10	0.02	-0.001	0.03	-0.013	0.05	0.02	0.28	0.01	1.36	**-0.70**	-0.46	0.72	-0.81	0.19	-0.01	-0.31	0.11	0.38	-1.24	-1.62	1.01	0.54	0.32	0.29	0.004	0.17
11	-0.06	-0.01	-0.36	0.17	-0.04	0.06	0.25	0.02	1.88	-0.41	**-0.77**	1.18	-1.32	0.33	-0.01	-0.26	0.14	0.33	-1.53	-1.31	1.04	0.56	0.16	0.33	-0.003	0.35
12	-0.08	-0.01	-0.40	0.21	-0.08	0.05	0.19	0.02	1.84	-0.39	-0.71	**1.29**	-1.10	0.32	-0.01	-0.25	0.11	0.39	-1.45	-1.01	0.73	0.36	0.10	0.30	-0.004	0.38
13	0.03	0.001	-0.15	0.09	0.03	0.08	0.16	0.0001	0.93	-0.20	-0.36	0.50	**-2.82**	0.76	-0.01	-0.20	0.13	0.24	-0.61	-0.87	1.65	0.39	0.12	0.20	-0.025	0.08
14	0.01	-0.002	-0.23	0.14	0.008	0.01	0.19	-0.001	0.75	-0.15	-0.29	0.47	-2.43	**0.88**	-0.005	-0.35	0.14	0.43	-0.41	-0.76	1.14	0.38	0.09	0.21	-0.022	0.19
15	0.04	0.0022	-0.02	0.01	0.06	-0.03	0.33	0.018	1.43	-0.47	-0.51	0.66	-1.25	0.35	**-0.01**	-0.55	0.11	0.68	-1.15	-2.23	1.18	0.83	0.31	0.40	0.003	0.21
16	0.04	-0.0001	-0.12	0.06	0.07	-0.05	0.32	0.013	0.89	-0.33	-0.31	0.49	-0.87	0.47	-0.012	**-0.66**	0.08	0.85	-0.68	-1.70	0.49	0.67	0.21	0.36	0.003	0.28
17	0.01	-0.001	-0.28	0.15	-0.008	0.09	-0.02	-0.003	0.79	-0.25	-0.34	0.48	-1.19	0.34	-0.005	-0.18	**0.30**	0.16	-0.56	-0.54	0.65	0.15	0.03	0.32	-0.007	0.10
18	0.03	-0.001	-0.12	0.07	0.05	-0.05	0.37	0.018	0.87	-0.32	-0.30	0.52	-0.82	0.45	-0.011	-0.66	0.06	**0.83**	-0.67	-1.67	0.51	0.71	0.21	0.33	0.002	0.41
19	-0.01	-0.003	-0.16	0.10	-0.032	0.04	0.095	0.006	1.94	-0.49	-0.67	1.05	-0.97	0.20	-0.01	-0.25	0.10	0.32	**-1.78**	-1.42	0.97	0.56	0.21	0.28	0.001	0.06
20	0.10	0.001	0.01	0.005	0.062	-0.002	0.33	0.02	1.38	-0.50	-0.45	0.58	-1.08	0.29	-0.014	-0.49	0.073	0.62	-1.12	**-2.25**	1.09	0.88	0.32	0.38	0.006	0.17
21	0.02	0.001	-0.09	0.06	0.034	0.02	0.10	0.003	1.08	-0.36	-0.41	0.47	-2.36	0.51	-0.008	-0.16	0.10	0.22	-0.87	-1.24	**1.98**	0.48	0.22	0.27	-0.015	-0.004
22	0.06	0.0004	-0.03	0.01	0.061	-0.03	0.30	0.015	1.22	-0.38	-0.44	0.47	-1.13	0.34	-0.011	-0.44	0.05	0.59	-1.01	-2.01	0.97	**0.99**	0.28	0.33	0.003	0.22
23	0.03	0.002	0.10	-0.02	0.062	-0.02	0.35	0.015	0.95	-0.54	-0.32	0.31	-0.79	0.19	-0.01	-0.33	0.024	0.42	-0.92	-1.75	1.05	0.68	**0.41**	0.20	0.007	0.09
24	0.002	-0.0003	-0.21	0.09	0.037	0.022	0.34	0.024	1.32	-0.42	-0.53	0.81	-1.19	0.38	-0.01	-0.48	0.20	0.57	-1.03	-1.76	0.88	0.68	0.17	**0.48**	-0.0002	0.38
25	-0.003	0.001	0.13	-0.08	-0.002	-0.075	0.14	0.015	-0.16	-0.09	0.08	-0.18	2.16	-0.59	-0.001	-0.06	-0.07	0.06	-0.08	-0.39	-0.93	0.09	0.09	-0.003	**0.03**	0.10

Residual value = -0.012 rG= Genotypic correlation coefficient of number of fruits per tree

1. Plant height
2. Plant girth
3. Canopy spread (E-W)
4. Canopy spread (N-S)
5. Leaf area
6. No. of flowers/10cm^2
7. Fruit set percentage
8. No. of fruits/m^2
9. Fruit weight
10. Fruit length
11.Fruit breadth
12. Thickness of pericarp
13. Fresh mace weight
14. Dry mace weight
15. Fresh nut weight
26. Ratio of nut to mace
16.Dry nut weight
17.Shell thickness
18. Kernel weight
19. Fruit volume
20. Nut volume
21. Mace volume
22. Kernel volume
23. Nut length
24. Nut breadth
25. No. of fruits/tree

negative direct effect was exerted by fresh mace weight (-2.82), nut volume (-2.25) and fruit volume (-1.78). Thondaiman and Rajamani (2014) in cocoa confirmed that pod characters should be considered with great emphasis as main yield components because these traits showed direct effects on yield. Findings of the present study again strongly confirms the reliability of the characters viz., fruit weight, mace volume, thickness of pericarp, kernel volume, dry weight of mace, fruit set percentage and number of fruits per tree towards selection of superior and high yielding genotypes.

The first ten principal component axes explained 86.90 per cent of the yield variability among the morphotypes under study (Table 3). The remaining fifteen axes contributed 13.01 per cent of the variability. The first principal component, plant height accounted 34.04 per cent contribution to the yield. While the subsequent nine principal components contributed 14.89, 10.75, 8.08, 5.20, 4.50, 3.55, 3.0 and 2.86 per cent, respectively. These characters were plant girth, canopy spread in E-W and N-S, leaf area, no. of flowers/10cm^2, fruit set percentage, no. of fruits/m^2 and fruit weight, respectively. The character contributing the maximum to the yield should be given greater emphasis in breeding programme (Majumder *et al*., 2013). The first principal yield component has additive gene action, which suggests that nutmeg breeding programme aimed for higher fruit yield should be through selection method of breeding strategy.

Yield levels in forty six morphotypes were differentiated by the Eigen vector ($\geq$ 0.7) into different principal components (Table 4). The fruit weight, fruit length, fruit breadth, thickness of pericarp, fresh as well as dry nut weight, volume of fruit, nut and kernel and nut breadth were distinguished by the Eigen vector in the first principal component. The second principal component had plant height and canopy spread in both E-W & N-S directions which discriminated the forty six accessions. Number of fruits per tree significantly distinguished the yield levels in nutmeg in the third principal component. These traits played major role in all the four components for determining the yield of nutmeg.

Table 3. Eigen values and per cent variation of yield contributing traits of nutmeg

Sl. No.	Principal component axis	Eigen values	Variation (%)	Cumulative variation (%)
1	Plant height (m)	8.853	34.04	34.04
2	Plant girth (cm)	3.874	14.89	48.94
3	Canopy spread (E-W)-(m)	2.796	10.75	59.70
4	Canopy spread (N-S)-(m)	2.103	8.08	67.79
5	Leaf area (cm^2)	1.352	5.20	72.99
6	No. of flowers/10cm^2	1.171	4.50	77.49
7	Fruit set percentage	0.923	3.55	81.04
8	No. of fruits/m^2	0.781	3.00	84.04
9	Fruit weight (g)	0.744	2.86	86.90
10	Fruit length (mm)	0.520	2.00	88.90
11	Fruit breadth (mm)	0.462	1.77	90.68
12	Thickness of pericarp (mm)	0.396	1.52	92.20
13	Fresh mace weight (g)	0.361	1.38	93.59
14	Dry mace weight (g)	0.335	1.28	94.88
15	Fresh nut weight (g)	0.215	0.82	95.71
16	Dry nut weight (g)	0.190	0.73	96.44
17	Shell thickness (mm)	0.169	0.65	97.09
18	Kernel weight(g)	0.152	0.58	97.67
19	Fruit volume (cm^3)	0.134	0.51	98.19
20	Nut volume (cm^3)	0.117	0.44	98.64
21	Mace volume (cm^3)	0.104	0.39	99.04
22	Kernel volume (cm^3)	0.075	0.29	99.33
23	Nut length (mm)	0.059	0.22	99.56
24	Nut breadth (mm)	0.046	0.17	99.73
25	No. of fruits/tree	0.039	0.15	99.88
26	Ratio of nut to mace	0.030	0.11	100.00

Table 4. Principal component analysis on nutmeg yield traits (non-rotated values)

Sl. No.	Traits	Principal components (Eigen vector)			
		1	2	3	4
1	Plant height (m)	0.014	0.724	0.241	0.077
2	Plant girth (cm)	0.142	0.691	0.152	0.125
3	Canopy spread (E-W)-(m)	0.292	0.807	0.056	-0.117
4	Canopy spread (N-S)-(m)	0.289	0.798	-0.005	-0.121
5	Leaf area (cm^2)	-0.062	0.573	0.076	0.179
6	No. of flowers/$10cm^2$	0.030	0.111	-0.272	0.262
7	Fruit set percentage	0.496	0.021	0.520	-0.442
8	No. of fruits/m^2	0.361	0.116	0.614	-0.360
9	Fruit weight (g)	0.832	0.136	-0.058	0.352
10	Fruit length (mm)	0.729	-0.229	0.068	0.295
11	Fruit breadth (mm)	0.827	0.307	-0.032	0.295
12	Thickness of pericarp (mm)	0.711	0.432	-0.003	0.294
13	Fresh mace weight (g)	0.560	0.063	-0.656	-0.370
14	Dry mace weight (g)	0.549	0.134	-0.517	-0.515
15	Fresh nut weight (g)	0.847	-0.342	0.067	0.051
16	Dry nut weight (g)	0.723	-0.229	0.127	-0.244
17	Shell thickness (mm)	0.411	0.202	-0.311	0.093
18	Kernel weight(g)	0.688	-0.199	0.167	-0.335
19	Fruit volume (cm^3)	0.706	0.071	-0.068	0.563
20	Nut volume (cm^3)	0.834	-0.383	0.084	0.073
21	Mace volume (cm^3)	0.586	-0.058	-0.492	-0.043
22	Kernel volume (cm^3)	0.731	-0.316	0.063	-0.027
23	Nut length (mm)	0.659	-0.406	0.120	0.116
24	Nut breadth (mm)	0.844	-0.056	0.050	-0.053
25	No. of fruits/tree	-0.077	-0.270	0.778	0.384
26	Ratio of nut to mace	0.386	0.331	0.503	-0.411

The separation of the accessions under study into five clusters proves the high level of variability for yield traits (Fig.1). Cluster I housed only one nutmeg accession (Acc. 9) which was noticed distinct form other accessions with respect to the number of fruits per tree along with good nutmeg and mace weight.

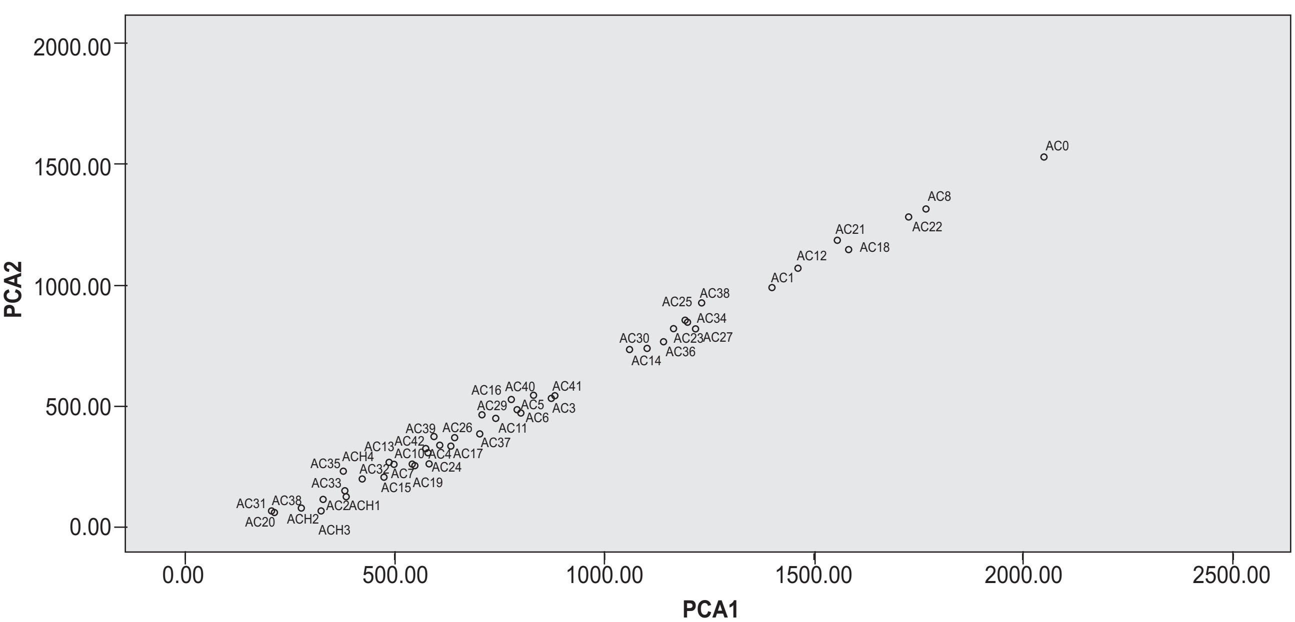

Fig. 1. Grouping of nutmeg accessions based on principal component analysis studied for yield contributing traits

This accession bears the highest number of fruits (4420) against the mean of 1398; mace weight 2.52 g and 1.44 g against the mean of 2.25 g and 1.12 g fresh as well as dry, respectively; nut weight 11.44 g and 8.37 g against the mean of 10.01 g and 7.07 g fresh as well as dry, respectively. Cluster II had two accessions viz., Acc. 8 and Acc. 22. Though these accessions are categorised into high yielding types along with Acc. 9 of cluster I, these cluster members possessed medium nut and mace weight. Further, cluster III included four cluster members viz., Acc. 1, Acc. 12, Acc. 18 and Acc. 21. All the trees in this group are medium yielders with respect to number of fruits per tree as well as other yield donating traits. In cluster IV, there were eight accessions which were medium yielding with average nut and mace weight, and other yield related traits. All the 31 accessions in cluster IV were very much similar in yield attributing traits. In this group both female as well as monoecious accessions clustered together because of average values in number of fruits per tree and nut and mace characters.

This study revealed that fruit weight, mace volume and thickness of pericarp had a very high direct effect on yield and kernel volume, dry weight of mace, and fruit set percentage had positive effect through number of fruits/tree. The PCA on yield parameters has shown that number of fruits/tree is most contributing towards the yield, followed by plant girth, canopy spread in E-W and N-S, leaf area, no. of flowers/10cm^2, fruit set percentage, and fruit weight. The skewness and kurtosis for the leading traits were number of fruits/tree as well as ratio of nut to mace and thus we suggest the selection method for breeding nutmeg for higher yield.

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