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MORPHOLOGICAL AND MICROSCOPIC ANALYSIS OF FIVE *CURCUMA* SPECIES GROWN IN SRI LANKA USING MULTIVARIATE TEST

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ABSTRACT: *Curcuma* is an important genus used in Traditional Medicine in the world. Due to similar morphological characters and same Sinhalese vernacular names of *Curcuma* species, adulteration or substitution takes place. The current study was conducted to understand the similarities in morphological and microscopic characters by analyzing data using multivariate test on five species available in Sri Lanka; *C. albiflora*, *C. aromatic*, *C. longa*, *C. oligantha,* and *C. zedoaria*. Whole plants of *Curcuma* species were collected in 2016, from wet and dry zones of Sri Lanka. Voucher specimens of the plants were authenticated from National Herbarium, Peradeniya, Sri Lanka. Morphological characters of five *Curcuma* species and microscopic characters of five *Curcuma* species using 5 observations of each plant were analyzed. An experiment was conducted as per WHO guidelines and other published data. Statistical tests were performed using Minitab 17. Multivariate test was used to determine the complex relationship among variables by simple correspondence analysis. Analyses examined the relationships between the 25 observations and the associations between variables in two dimensions and similar morphological and microscopic observations were identified from their positions. Statistical analysis of the current study showed differentiation by morphological and microscopic characters of *Curcuma* species. Morphologically *C. zedoaria* and *C. longa* are similar. Microscopically, *C. zedoaria* and *C. albiflora* showed more similarity, In contrast, *C. aromatica* and *C. longa* clustered as another group. Therefore, this analysis can be used to identify commercial samples of *Curcuma* species more effectively.

INTRODUCTION: Purpose and Rationale: Among plant geniuses, *Curcuma* claimed to have clinically valuable medicinal plants in indigenous and traditional medicine in the world [1]. Genus *Curcuma* (family Zingiberaceae) comprises about 100 species all over the world, only 5 species are reported in Sri Lanka (*C. albiflora*, *C. aromatica*, *C. longa*, *C. oligantha*, and *C. zedoaria*) [2].

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Curcuma is claimed as a potential source of raw material in herbal medicine to combat a variety of ailments such as arthritis, cancer, diabetes, cough, skin disorders, and oxidative stress-related pathogenesis, etc [3-7]. Medicinally, most of the *Curcuma* species have medicinal importance with its action such as anti-inflammatory, hypocholesterolemic, choleretic, anti-microbial, anti-rheumatic, antifibrotic, antivenomous, antidiabetic, antihepatotoxic anticancerous, anti-oxidant, toxicant, larvicidal, pheromone, insecticidal, anti-plasmodium, mutagenic, genotoxic, hyper-protective, platelet aggregation inhibitor, anti-arthritic, COX-1 inhibitor, antiviral, antiproliferative, cytotoxic, and apoptosis etc. properties [8].

In addition to its medicinal importance, *Curcuma* oil is used in aromatherapy and the perfume industry [9]. Biologically active compounds have been isolated and detected in *Curcuma* species in the past decades.

Four species, namely *C. longa*, *C. aromatica*, *C. oligantha*, and *C. zedoaria* are used in Traditional Medicine in Sri Lanka. *C. longa* is one of the most valuable species of the *Curcuma* genus. *C. aromatica*, *C. longa*, and *C. zedoaria* have been used in various indigenous medical systems. Under the name *Harankaha*, regionally people use various plants for their herbal preparations; *C. zedoaria*, *C. aromatica*, *C. albiflora*, and *Zingiber zerumbet* [2]. Due to its similar morphological characters and same Sinhalese vernacular names, these species are likely to be adulterated. Statistical analysis of the characters of plants concerning similarity can put into the same group. Therefore, the present study was undertaken to analyze the morphological and microscopic features of five *Curcuma* species statistically using multivariate test [10].

MATERIALS AND METHODS: Whole plants of *Curcuma* species were collected in the year 2016 from wet and dry zones of Sri Lanka in the flowering season; *C. albiflora* (Kitulgala, Kegalle and Erathna, Ratnapura district), *C. aromatica* (Erathna, Ratnapura), *C. longa* (Kahathuduwa, Colombo district), *C. oligantha* (Hebarawa, Badulla district), *C. zedoaria* (Gonapola, Colombo district). Voucher specimens of the plants (herbariums) were authenticated and deposited in the National Herbarium, Peradeniya, Sri Lanka, and Herbal Technology Section, ITI for future reference. Morphological and microscopical characters of five *Curcuma* species using 5 observations of each plant were used. To study Pharmacognostical parameters, preparation, preservation, and storage of plants and experiments were done according to WHO guidelines and other published data [11-14]. Morphological studies, leaf, flower, and rhizome, were observed through Leica MS 5 microscope separately, and thin hand-cut specimens were observed under Labomed (Sigma, Labo America, Inc. U.S.A.) microscope with 100x and 400x magnification for the microscopic studies.

Statistical Analysis: Statistical tests were performed using Minitab 17. Multivariate test was used to determine the complex relationship among variables. Ten morphological features and eight microscopic features were analyzed by simple correspondence analysis and by cluster variable method. Analyses examined the relationships between the 25 observations and the associations between variables in two dimensions and similar morphological and microscopic observations were identified from their positions [10, 15-19].

RESULTS AND DISCUSSION:

Morphological Characters of Five *Curcuma* Species: Some of the morphological characters are reported in **Table 1**.

TABLE 1: MORPHOLOGICAL COMPARISON OF FIVE *CURCUMA* SPECIES [19]

Morphological features	*C. albiflora*	*C. aromatica*	*C. longa*	*C. oligantha*	*C. zedoaria*
Height	35 ± 15 cm	170 ± 25 cm	120 ± 15 cm	50 ± 15 cm	160 ± 20 cm
Length of petiole	9 cm	90 cm	18 cm	1.5 cm	15 cm
Size of lamina	15±3×7±1cm	50±20×12±2 cm	40±10×7±1 cm	23±5×6±1 cm	45±20×10±2 cm
Number of leaves	5-6	5-7	3-5	5-12	4-6
Peduncle height	12 cm	5-8 cm	6-7 cm	5-7 cm	5-8 cm
Size of inflorescence	7 × 6 cm	15-30 × 9 cm	10-15 × 5-7 cm	3-7 cm	10-18 × 6-8 cm
Calyx	1.3-1.8 cm	2 cm	1.5 cm	1.5 cm	8 mm
Leaf lower surface	Glabrous (0)	Pubescent (2)	Glabrous(0)	Glabrous(0)	Lightly pubescent(1)

By cluster variable analysis of morphological characters of five species, *C. longa* and *C. zedoaria* have similar morphological characters **Fig. 1**. In the row profile, petiole length, and lower surface of *C. aromatica* has shown a higher percentage (12 - 13% and 13.3 - 13.7%) respectively **Table 2**. Lower surface was more pubescent in *C. aromatica*.

Table 3 gives a summary of the decomposition of the 10 × 25 contingency table into 9 components. The column labeled. Inertia contains the χ squared / n value accounted for by each component. Of the total inertia, 0.1368 %, 58.2% was accounted for by the first component, 32.38% by the second component, and so on.

TABLE 2: ROW PROFILE OBTAINED FROM MORPHOLOGICAL CHARACTERS

	1	2	3	4	5	6	7	8	9
HT - Plant Height	0.012	0.013	0.014	0.015	0.017	0.059	0.061	0.064	0.067
LL - Leaf Length	0.015	0.016	0.017	0.018	0.015	0.050	0.069	0.055	0.059
LW - Leaf Width	0.031	0.036	0.031	0.036	0.031	0.054	0.058	0.054	0.058
PL - Petiole Length	0.013	0.014	0.013	0.015	0.011	0.126	0.133	0.140	0.129
NL - Number of Leaves	0.034	0.041	0.048	0.034	0.041	0.034	0.048	0.048	0.041
FPH - Flower Peduncle Height	0.065	0.070	0.062	0.075	0.081	0.027	0.032	0.038	0.043
IL - Inflorescence Length	0.026	0.026	0.023	0.023	0.026	0.056	0.113	0.075	0.094
IW - Inflorescence Width	0.035	0.035	0.029	0.023	0.035	0.052	0.058	0.047	0.064
CX - Calyx	0.034	0.037	0.048	0.045	0.048	0.050	0.053	0.053	0.053
LLS - Leaf Lower Surface	0.000	0.000	0.000	0.000	0.000	0.133	0.133	0.133	0.133
Mass	0.017	0.019	0.018	0.019	0.020	0.064	0.072	0.070	0.073
	10	11	12	13	14	15	16	17	18
HT - Plant Height	0.065	0.042	0.047	0.043	0.046	0.045	0.017	0.022	0.019
LL - Leaf Length	0.064	0.040	0.050	0.043	0.048	0.045	0.023	0.028	0.024
LW - Leaf Width	0.054	0.031	0.036	0.031	0.036	0.031	0.027	0.031	0.027
PL - Petiole Length	0.137	0.025	0.028	0.035	0.027	0.032	0.002	0.002	0.002
NL - Number of Leaves	0.034	0.020	0.027	0.034	0.041	0.027	0.034	0.054	0.082
FPH - Flower Peduncle Height	0.043	0.032	0.032	0.038	0.038	0.032	0.027	0.027	0.032
IL - Inflorescence Length	0.105	0.038	0.056	0.049	0.053	0.045	0.011	0.015	0.011
IW - Inflorescence Width	0.070	0.029	0.029	0.035	0.041	0.041	0.023	0.029	0.035
CX - Calyx	0.056	0.040	0.042	0.045	0.037	0.040	0.040	0.037	0.042
LLS - Leaf Lower Surface	0.133	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Mass	0.074	0.037	0.043	0.041	0.043	0.041	0.017	0.022	0.020
	19	20	21	22	23	24	25	Mass	
HT - Plant Height	0.021	0.020	0.055	0.062	0.059	0.057	0.058	0.510	
LL - Leaf Length	0.025	0.027	0.045	0.064	0.050	0.055	0.059	0.178	
LW - Leaf Width	0.031	0.027	0.045	0.049	0.045	0.054	0.054	0.039	
PL - Petiole Length	0.002	0.002	0.021	0.025	0.022	0.017	0.028	0.126	
NL - Number of Leaves	0.061	0.048	0.027	0.034	0.041	0.027	0.041	0.026	
FPH - Flower Peduncle Height	0.032	0.038	0.022	0.022	0.027	0.032	0.032	0.033	
IL - Inflorescence Length	0.019	0.026	0.019	0.023	0.023	0.026	0.019	0.047	
IW - Inflorescence Width	0.041	0.041	0.035	0.035	0.041	0.047	0.052	0.030	
CX - Calyx	0.045	0.048	0.021	0.019	0.024	0.021	0.021	0.007	
LLS - Leaf Lower Surface	0.000	0.000	0.067	0.067	0.067	0.067	0.067	0.003	
Mass	0.022	0.022	0.044	0.052	0.048	0.048	0.051		

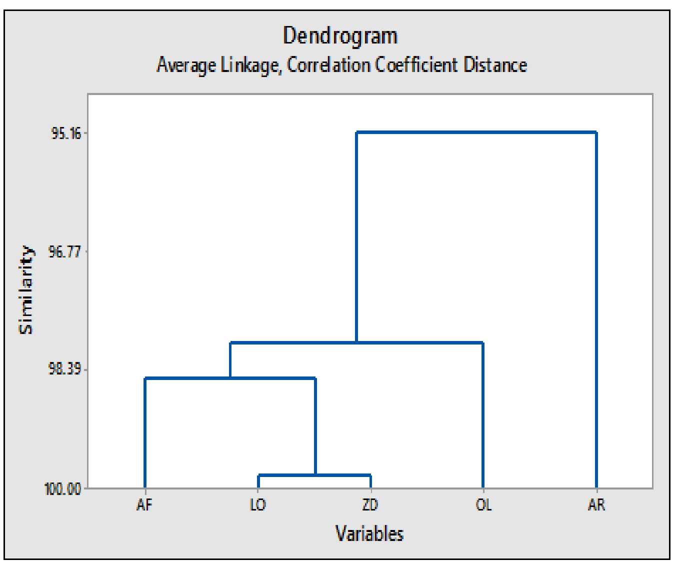

FIG. 1: CLUSTER VARIABLE ANALYSIS OF DENDROGRAM OBTAINED FROM MORPHOLOGICAL CHARACTERS; AF: *C. ALBIFLORA*, LO: *C. LONGA*, ZD: *C. ZEDOARIA*, OL: *C. OLIGANTHA*, AR: *C. AROMATICA*

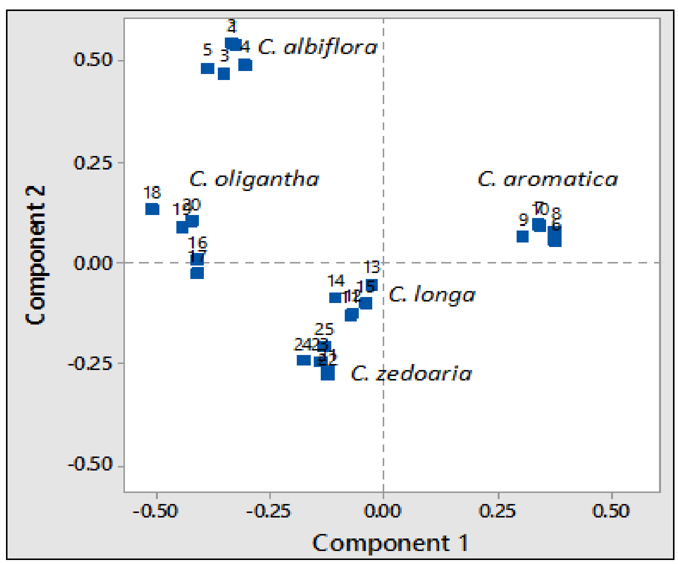

FIG. 2: COLUMN PLOT OBTAINED FROM MORPHOLOGICAL CHARACTERS

TABLE 3: ANALYSIS OF CONTINGENCY TABLE OBTAINED FROM MORPHOLOGICAL CHARACTERS

Axis	Inertia	Proportion	Cumulative
1	0.0796	0.5820	0.5820
2	0.0443	0.3238	0.9059
3	0.0063	0.0461	0.9519
4	0.0042	0.0308	0.9827
5	0.0010	0.0075	0.9902
6	0.0008	0.0056	0.9958
7	0.0003	0.0021	0.9980
8	0.0002	0.0014	0.9993
9	0.0001	0.0007	1.0000
Total	0.1368		

Since the number of components was not specified, Minitab calculates 2 components. The column labeled Qual (quality) in **Table 4** is the proportion of the row inertia represented by the two components. The rows plant height, petiole length, and peduncle height, with the quality of 0.950, 0.996 and 0.931 respectively were observed, which are best represented among the rows by the two-component breakdown.

The column labeled Inert is the proportion of the total inertia contributed by each row. Thus, petiole length contributes 42.1% to the total χ squared statistic. The column labeled Corr represents the contribution of the component to the inertia of the row. Thus, Component 1 accounted for most of the inertia of petiole length (Coor = 0.906) but explains little of the inertia of plant height (Coor = 0.073). Contr, the contribution of each row to the axis inertia, shows that petiole length and peduncle height contribute the most, with plant height and calyx contributing to a smaller degree, to Component 1.

TABLE 4: ROW CONTRIBUTIONS

Name	Qual	Mass	Inert	Component 1			Component 2		
				Coord	Corr	Contr	Coord	Corr	Contr
Plant Height	0.950	0.510	0.082	-0.040	0.073	0.010	-0.139	0.877	0.221
Leaf Length	0.764	0.178	0.033	-0.107	0.448	0.026	-0.090	0.317	0.033
Leaf Width	0.848	0.039	0.029	-0.235	0.555	0.027	0.171	0.293	0.026
Petiole Length	0.996	0.126	0.421	0.642	0.906	0.655	0.202	0.090	0.117
Number Of Leaves	0.748	0.026	0.111	-0.544	0.507	0.096	0.374	0.241	0.082
Peduncle Height	0.931	0.033	0.214	-0.549	0.338	0.124	0.727	0.594	0.391
Inflorescence Length	0.599	0.047	0.050	0.159	0.173	0.015	0.250	0.427	0.067
Inflorescence Width	0.801	0.030	0.029	-0.237	0.437	0.021	0.217	0.364	0.032
Calyx	0.864	0.007	0.018	-0.353	0.332	0.010	0.447	0.532	0.030
Leaf Lower Surface	0.645	0.003	0.014	0.663	0.612	0.015	-0.153	0.033	0.001

Microscopic Characters of Five *Curcuma* Species: Some of microscopic characters of five *Curcuma* species were reported **Table 5**.

TABLE 5: COMPARATIVE MICROSCOPIC CHARACTERS OF FIVE *CURCUMA* SPECIES [20, 21]

Description	*C. albiflora*	*C. aromatica*	*C. longa*	*C. oligantha*	*C. zedoaria*
Number of layers of palisade	2	1	1	1	1
Periderm	15-16 layers	8-10 layers	2-4 layers	5-6 layers	14-15 layers
Primary vascular bundles	15-20 vascular bundles in the inner core	50-60 vascular bundles in the inner core of the outer zone	70-80 vascular bundles evenly distributed	15-20 vascular bundles in the inner core	90-120 bundles distributed evenly in the outer zone
Cambium	3-4 layers	2 layers	2 layers	2-4 layers	2-3 layers
Starch grains	Eccentric and concentric, Striations and hilum of few starch grains, Globular, a circular, elongated, oval and semicircular shape, 5-20/cell small: 5-10 µm, medium: 15-25 µm,	Numerous in the inner and outer core, spindle-shaped, eccentric, 5-20/cell, two sizes; 18 ± 1 µm and 24 ± 1 µm	Numerous in the inner and outer core, triangular shaped, eccentric, 12-20/cell contain two sizes of starch grains; 45 ± 15 µm and 30 ±5 µm	Less, triangular and dumbbell shape, 1-10/cell small: 5-7 µm, medium: 12-16 µm, and large: 20-27 µm	Numerous in inner and outer core, large and rod-shaped, eccentric, 5-20/cell 25-40 µm circular, 85-95 µm polygonal or sector-shaped, and 45-75 µm polygonal.

Crystals	and large: 30 µm 5 ± 2 µm and 10 ± 2 µm	5 ± 2 µm 12 ± 2 µm, 20 ± 1 µm, and rosette crystals	cuboidal (20 ± 5 µm), hexagonal (45 ± 5 µm), and diamond-shaped (35 ± 5 µm) prismatic crystals	prismatic crystals; 20 ± 2µm, 30 ± 2 µm, and 45 ± 2 µm	5 ± 2 µm 10 ± 2 µm, 20 ± 2 µm, and rosette crystals
Palisade ratio	1:5-7	1:4-6	1:5-7	1:5-8	1:4-5
Stomatal index Up	3%	3.2%	3%	2%	3.4%
Stomatal index Lo	13%	13.8%	9%	7%	14%

Morphological and microscopic pictures were displayed in **Plate 1**.

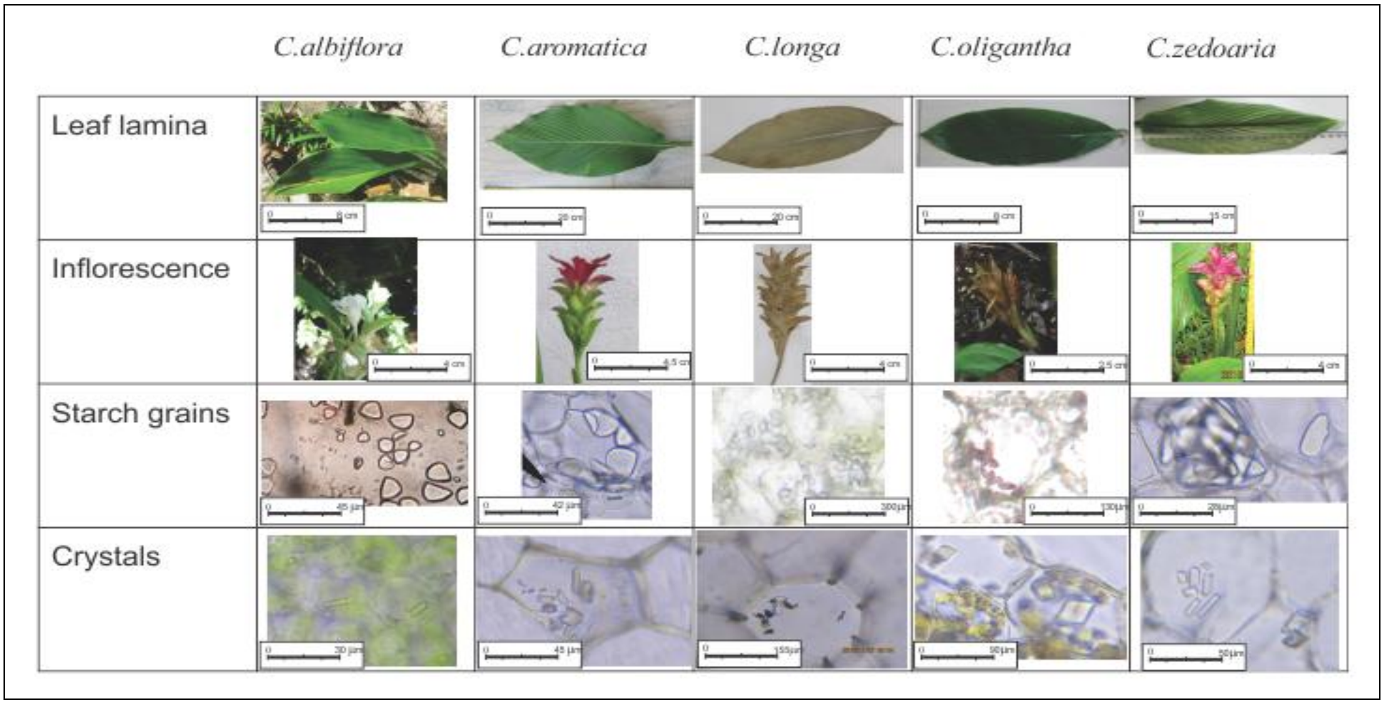

PLATE 1: COMPARATIVE MORPHOLOGICAL AND MICROSCOPIC STUDIES OF FIVE *CURCUMA* SPECIES

As per cluster variable analysis, *C. albiflora* and *C. zedoaria* shows similarity, *C. aromatica* and *C. longa* shows similarity by microscopical features **Fig. 3**. Further by column plot, *C. aromatica* and *C. longa* showed similar microscopical characters **Fig. 4**.

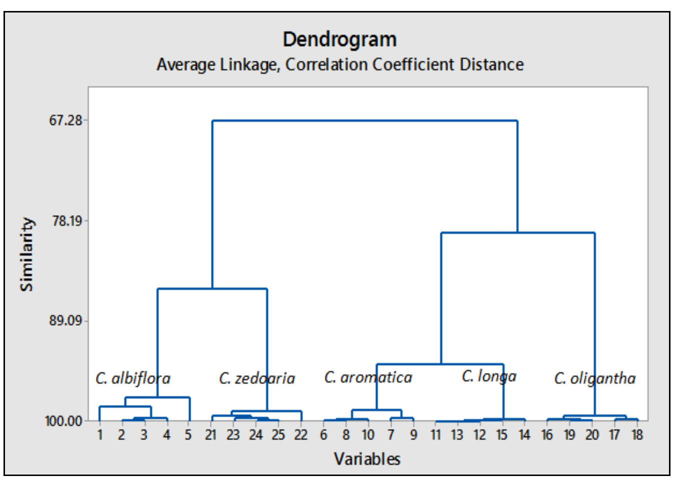

FIG. 3: CLUSTER VARIABLE ANALYSIS OF DENDROGRAM OBTAINED FROM MICROSCOPICAL CHARACTERS

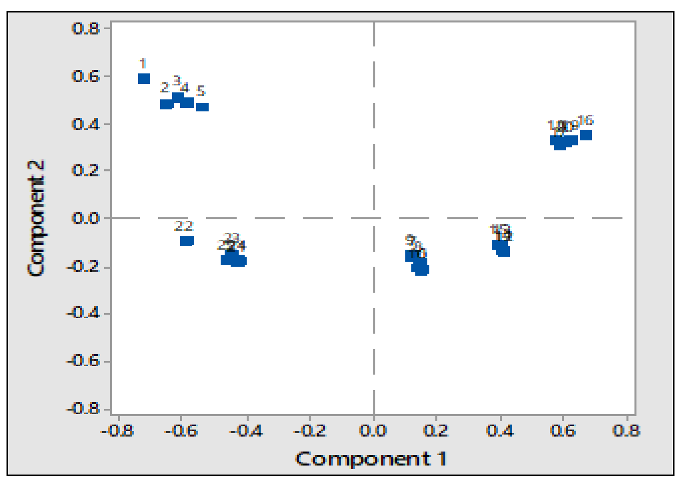

FIG. 4: COLUMN PLOT OBTAINED FROM MICROSCOPICAL CHARACTERS

TABLE 6: ROW PROFILES OBTAINED FROM MICROSCOPICAL CHARACTERS

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Starch grains1	0.008	0.010	0.011	0.013	0.016	0.029	0.031	0.031	0.029
Starch grains 2	0.016	0.018	0.020	0.022	0.025	0.026	0.026	0.027	0.026
Starch grains 3	0.067	0.065	0.067	0.067	0.067	0.000	0.000	0.000	0.000
Crystals 1	0.017	0.017	0.020	0.020	0.023	0.017	0.017	0.020	0.020
Crystals 2	0.018	0.018	0.019	0.019	0.021	0.021	0.021	0.023	0.023
Crystals 3	0.000	0.000	0.000	0.000	0.000	0.032	0.032	0.034	0.032
Stomatal index U	0.040	0.040	0.053	0.026	0.040	0.040	0.040	0.042	0.046
Stomatal index L	0.045	0.049	0.042	0.045	0.049	0.048	0.047	0.050	0.046
Number of palisade	0.067	0.067	0.067	0.067	0.067	0.033	0.033	0.033	0.033
Periderm	0.064	0.064	0.068	0.068	0.064	0.034	0.034	0.038	0.042
cambium	0.048	0.048	0.063	0.063	0.048	0.032	0.032	0.032	0.032
Primary vascular bundles	0.011	0.015	0.014	0.015	0.013	0.037	0.039	0.041	0.043
Starch grains per cell	0.018	0.036	0.043	0.054	0.072	0.018	0.072	0.036	0.054
Palisade ratio	0.036	0.036	0.043	0.051	0.051	0.029	0.029	0.036	0.043
mass	0.020	0.022	0.024	0.025	0.026	0.027	0.030	0.030	0.031
	10	11	12	13	14	15	16	17	18
Starch grains1	0.031	0.073	0.081	0.077	0.098	0.090	0.020	0.021	0.023
Starch grains 2	0.027	0.032	0.033	0.034	0.035	0.037	0.021	0.029	0.027
Starch grains 3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Crystals 1	0.023	0.067	0.070	0.074	0.077	0.080	0.067	0.067	0.070
Crystals 2	0.025	0.079	0.083	0.085	0.086	0.088	0.053	0.053	0.055
Crystals 3		0.056	0.058	0.061	0.063	0.064	0.032	0.072	0.074
Stomatal index U	0.033	0.040	0.040	0.040	0.053	0.040	0.026	0.040	0.026
Stomatal index L	0.045	0.031	0.031	0.028	0.035	0.035	0.024	0.024	0.028
Number of palisade	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033
Periderm	0.042	0.008	0.008	0.013	0.013	0.017	0.021	0.021	0.025
cambium	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.048
Primary vascular bundles	0.045	0.052	0.054	0.055	0.057	0.058	0.011	0.013	0.013
Starch grains per cell	0.018	0.043	0.051	0.058	0.065	0.072	0.007	0.018	0.036
Palisade ratio	0.043	0.036	0.036	0.043	0.051	0.043	0.036	0.043	0.043
mass	0.030	0.048	0.050	0.052	0.056	0.056	0.028	0.031	0.032
	19	20	21	22	23	24	25	mass	
Starch grains1	0.024	0.026	0.041	0.042	0.065	0.057	0.052	0.110	
Starch grains 2	0.023	0.026	0.091	0.101	0.087	0.094	0.098	0.168	
Starch grains 3	0.000	0.000	0.100	0.167	0.134	0.122	0.145	0.081	
Crystals 1	0.070	0.074	0.017	0.017	0.020	0.017	0.020	0.054	
Crystals 2	0.056	0.056	0.018	0.018	0.019	0.021	0.021	0.102	
Crystals 3	0.075	0.075	0.032	0.032	0.034	0.034	0.035	0.112	
Stomatal index U	0.040	0.026	0.045	0.046	0.042	0.052	0.046	0.000	
Stomatal index L	0.024	0.028	0.049	0.052	0.045	0.049	0.052	0.001	
Number of palisade	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.005	
Periderm	0.025	0.021	0.059	0.059	0.064	0.068	0.059	0.042	
cambium	0.048	0.063	0.032	0.032	0.048	0.048	0.032	0.011	
Primary vascular bundles	0.014	0.015	0.067	0.071	0.075	0.082	0.090	0.240	
Starch grains per cell	0.011	0.014	0.018	0.025	0.032	0.054	0.072	0.050	
Palisade ratio	0.051	0.058	0.029	0.029	0.036	0.036	0.029	0.025	
mass	0.032	0.033	0.055	0.064	0.063	0.066	0.070		

The table gives a summary of the decomposition of the 14 × 25 contingency table into 13 components. The column labeled. Inertia contains the χ squared / n value accounted for by each component. Of the total inertia, 0.64.03% is accounted for by the first component, 18.53% by the second component, and so on **Table 7**. The column labeled Qual (quality) in **Table 8** is the proportion of the row inertia represented by the two components.

The rows large starch grains, small crystals, and medium size crystals, with the quality of 0.960, 0.965 and 0.902 respectively were observed, which are best represented among the rows by the two-component breakdown. Large starch grains contribute 32.4 % to the total χ squared statistic. Component 1 accounted for most of the inertia of large storage grains (Coor = 0.909) but explains little of the inertia of the number of starch grains per cell (Coor = 0.014). Contr showed that large starch grains contribute the most, with stomatal index contributing to a smaller degree, to Component 1.

TABLE 7: ANALYSIS OF CONTINGENCY TABLE OBTAINED FROM MICROSCOPICAL CHARACTERS

Axis	Inertia	Proportion	Cumulative
1	0.2205	0.6403	0.6403
2	0.0638	0.1853	0.8256
3	0.0359	0.1042	0.9298
4	0.0162	0.0469	0.9768
5	0.0059	0.0171	0.9939
6	0.0008	0.0024	0.9963
7	0.0006	0.0018	0.9981
8	0.0004	0.0010	0.9991
9	0.0002	0.0006	0.9997
10	0.0001	0.0002	0.9999
11	0.0000	0.0001	1.0000
12	0.0000	0.0000	1.0000
13	0.0000	0.0000	1.0000
Total		0.3444	

TABLE 8: ROW CONTRIBUTIONS OBTAINED FROM MICROSCOPICAL CHARACTERS

					Component 1			Component 2		
ID	Name	Qual	Inert	Mass	Coord	Corr	Contr	Coord	Corr	Contr
1	Starch grains1	0.631	0.110	0.049	0.222	0.323	0.025	-0.217	0.308	0.081
2	Starch grains 2	0.643	0.168	0.059	-0.258	0.549	0.051	-0.107	0.094	0.030
3	Starch grains 3	0.960	0.081	0.324	-1.122	0.909	0.459	0.266	0.051	0.089
4	Crystals 1	0.965	0.054	0.072	0.581	0.727	0.082	0.333	0.238	0.093
5	Crystals 2	0.902	0.102	0.104	0.531	0.799	0.130	0.191	0.103	0.058
6	Crystals 3	0.810	0.112	0.159	0.622	0.788	0.196	0.104	0.022	0.019
7	Stomatal index U	0.321	0.000	0.000	-0.048	0.016	0.000	0.209	0.305	0.000
8	Stomatal index L	0.349	0.001	0.000	-0.178	0.137	0.000	0.221	0.212	0.000
9	Number of palisade	0.713	0.005	0.008	-0.199	0.076	0.001	0.577	0.637	0.028
10	Periderm	0.761	0.042	0.070	-0.486	0.415	0.045	0.444	0.346	0.130
11	Cambium	0.761	0.011	0.012	-0.073	0.015	0.000	0.514	0.746	0.047
12	Primary vascular bundles	0.913	0.240	0.077	-0.090	0.074	0.009	-0.304	0.839	0.347
13	Starch grains per cell	0.072	0.050	0.049	-0.070	0.014	0.001	0.140	0.057	0.015
14	Palisade ratio	0.709	0.025	0.17	0.092	0.036	0.001	0.397	0.672	0.061

CONCLUSION: Statistical analysis of the current study showed differentiation by morphological and microscopic characters of *Curcuma* species. Similar groups were identified; morphologically *C. zedoaria* and *C. longa* are similar according to the cluster variable method. Further *C. albiflora* and *C. oligantha* showed closer similarity than other species. Microscopically, *C. zedoaria* and *C. albiflora* showed more similarity. Moreover, *C. aromatica* and *C. longa* showed similarity.

But microscopically *C. oligantha* grouped into the separate group by cluster variable method. By column plot, *C. aromatica* and *C. longa* showed more similarity in terms of microscopic characters. As per morphological and microscopic characters, *Curcuma* species grown in Sri Lanka grouped to five different groups by simple corresponding methods. Therefore, this analysis can be used to identify more effectively.

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