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Character association and path coefficient analysis for improved traits in rambutan

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ABSTRACT

Variable types of rambutan collected from the natural diversity existing in the homesteads of Kerala were characterized and correlations among both qualitative and quantitative traits were studied by using Spearman and Pearson coefficient, respectively. The loading plot was drawn with principal components. The direct and indirect effects of component characters on fruit weight were also studied by path coefficient analysis. The collections having soft textured aril exhibited very strong adherence of aril to seed, whereas the collections having crispy aril were of free stone aril. The taste sweetness was found to tend towards soft textured and creamy white aril, but moved away from free seed aril. The loading plot revealed significant positive correlations between rachis length and leaflet width; leaflet width and leaflet length and between tree age and number of leaflets per leaf and a negative correlation between petiole length and leaflet width. Strong positive associations were observed between TSS and sugar content and among yield, fruit weight, fruit diameter, rind weight, aril weight and aril thickness whereas, a significant negative correlation between titrable acidity and TSS. The highest positive direct effect of aril weight and fruit weight on fruit yield reveals the true relationship between them and direct selection for this trait will be rewarding for yield improvement. The association of various characters provided information on the nature and relationship among various traits and it can certainly serve as an effective tool for the exploitation of a particular trait towards crop improvement.

Key words: *Nephelium lappaceum*, correlation, quantitative traits, qualitative traits, diversity.

INTRODUCTION

Rambutan (*Nephelium lappaceum* L.), commonly referred to as 'hairy litchi' is a medium-sized evergreen tree of the warm humid tropics belonging to Sapindaceae, a family that includes other important fruit crops such as litchi (*Litchi chinensis* Sonn.), longan (*Dimocarpus longan* Lour) and pulasan (*Nephelium mutabile* Blume). Native to Indonesia and Malaysia, rambutan is now commonly grown throughout South East Asia (Tindall, 10). In India, rambutan is mostly confined to Pathanamthitta and Kottayam districts of Kerala. There is tremendous potential for cultivation of this exotic fruit crop in the whole state of Kerala. The crop has also become one of the most treasured fruit particularly as a 'courtyard crop' or on its fringes in the homegardens (Muhamed and Kurien, 6). There exists great variability in rambutan because of the natural cross pollination and seed propagation. Wide morphological variations are also observed among plants as a consequence of which little uniformity is observed in the orchards and the fruits realised from them (Smith *et al*., 8).

Hiranpradit *et al*. (3) confirmed the association of some of the fruit traits while standardizing the quality of two commercial varieties of Thai rambutan, namely Rong-rien (RR) and See-chompoo (SC). They reported that fruit size (width, length, thickness), rind weight and thickness, aril weight and thickness and seed weight are highly correlated with fruit weight whereas aril colour, flavour and texture are not correlated with fruit weight. Among quality characters there is a report that there exists no correlation between ascorbic acid and total soluble solids content (Wall *et al*., 11). Several works have been conducted on the genetic wealth, crop regulation and post-harvest aspects of rambutan but to have an adequate information on the crop improvement studies association of different characters needs to be studied. Available information on this subject is meagre if not scanty. In this context, the present study was taken up with the prime objective of studying the association of both qualitative and quantitative traits including tree and fruit characters and secondary aim of establishing the direct and indirect effects of characters contributing to fruit yield and quality.

MATERIALS AND METHODS

The study was conducted in the major rambutan growing tracts of Kerala namely Pathanamthitta, Kottayam and Thrissur and a minor area of Idukki

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during the period from December 2014 to April 2016. A preliminary survey was conducted in these tracts to locate the variable rambutan trees by purposive sampling. A total of 100 variable types of rambutan were located from these four districts. Among these collections 86 trees were of seedling origin (natural types) and 14 trees were budded plants. All the collections were of productive and steady bearing nature except Col.003 and Col.011 which were male trees. All the characters including growth characters, leaf characters, inflorescence characters, fruit characters and seed characters were recorded as per the standard descriptor prescribed by IPGRI (4). Quantitative leaf characters were recorded as the average of 20 fully expanded representative leaves, collected when shoots are lignified and for qualitative characteristics the predominant first pair of leaflets from terminal leaflet was used. Inflorescence characters such as flower composition (Hermaphrodite Flower Functioning as Female, Hermaphrodite Flower Functioning as Male and True Male) and inflorescence shape (Pyramidal, Conical and Obtriangular) were recorded as the average of at least ten panicles from each collections at bloom period. Fruits were harvested from the different growing tracts from May, 2015 to September, 2015 coinciding with the ripening stage and were immediately observed for all morphological and biochemical characters in the laboratory of Dept. of Fruit Science, College of Horticulture, Kerala Agricultural University. All the characters were recorded as average of 20 well ripened fruits. Rind colour was observed at the time of fruit maturity and described with the help of Universal Colour Language (UCL) defined by the Inter-society Colour Council, National Bureau of Standards in 1946.

The data were analysed and interpreted by using the statistical tools like Spearman and Pearson coefficient, Path Coefficient Analysis and Principal Component Analysis. The association among qualitative characters was studied by using Spearman coefficient (non-parametric) whereas that of quantitative variables was explained by using Pearson coefficient (parametric) which provided the information on the nature and relationship among the various traits (Pearson, 7; Spearman, 9). The correlation between a particular cause and effect is partitioned into direct and indirect effects of the various causal factors on the effect factor through path coefficient analysis. The principle and techniques suggested by Wright (12) and Li (5) were used for the analysis using the formula given by Dewey and Lu (2). The loading plot was drawn to know the relation among various characters based on first two principal components by using the software Minitab 17 where the correlation between any two variables is approximated by the cosine of the angle between their vectors.

RESULTS AND DISCUSSION

The association among 14 qualitative characters *viz*., leaf colour, crown shape, flower composition, inflorescence shape, fruit shape, rind colour, spine texture, spine colour, aril colour, aril taste, aril texture, aril juiciness, adherence of aril to seed and seed shape was measured both at 0.05 and 0.01 using the Spearman correlation coefficient (non-parametric) (Table 1).

Correlation matrix formed with qualitative traits revealed high significant positive correlation between aril taste and aril texture (0.411) and aril taste and aril colour (0.314) which was significant at 1 per cent level. In addition, significant negative correlations were observed between aril texture and adherence of aril to seed (-0.713), rind colour and spine colour (-0.401) and aril taste and adherence of aril to seed (-0.318) at 0.01 level and between aril colour and adherence of aril (-0.227) to seed at 0.05 level.

Data on the association among the 32quantitative characters *viz.*, age of the tree, number of leaflets per leaf, rachis length, petiole length, leaflet length, leaflet width, percentage fruit set, length of fruit bunch, number of fruits per bunch, fruit length, fruit diameter, total fruit weight, rind thickness, rind weight, spine length, spine density, aril weight, aril thickness, seed length, seed width, seed weight, aril to fruit ratio, seed to fruit ratio, seed to aril ratio, total soluble solids, titrable acidity, total sugar, reducing sugar, non-reducing sugar, total carotenoids, ascorbic acid and fruit yield studied by Pearson correlation coefficient (parametric) are presented in Table 2.

Significant positive correlations were observed between rachis length and spine length (0.200), petiole length and seed width (0.261), leaflet width and fruit length (0.202) and percentage fruit set and number of fruits per bunch (0.331). The loading plot revealed positive correlation between rachis length and leaflet width; leaflet width and leaflet length; tree age and number of leaflets per leaf as indicated by the small acute angles between their vectors ($r=\cos 0=+1$). It was also observed a near zero correlation between leaflet width and number of leaflets per leaf as indicated by mutually near perpendicular vectors ($r=\cos 90=0$) and a negative correlation between leaflet width and length of petiole as indicated by the approximate angle of 180° between their vectors ($r=\cos 180= -1$) (Fig. 1).

Fruit yield expressed high significant positive correlations with fruit weight (0.654), aril weight

Table 1. Correlations among qualitative traits of rambutan.

	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14
R1	1													
R2	-0.052	1												
R3	-0.034	0.137	1											
R4	0.006	-0.055	**.202***	1										
R5	0.127	-0.062	-0.054	0.098	1									
R6	-0.029	-0.075	0.123	0.011	0.191	1								
R7	-0.065	0.14	-0.047	0.104	-0.045	-0.056	1							
R8	0.098	0.133	-0.015	0.033	-0.01	**-.401****	0.118	1						
R9	-0.019	0.131	0.17	-0.03	-0.09	0.027	0.015	-0.152	1					
R10	0.186	-0.094	-0.103	-0.006	-0.036	0.002	-0.019	-0.135	0.108	1				
R11	**.231***	0.109	-0.09	-0.031	-0.14	-0.17	0.017	0.029	**.314****	**.411****	1			
R12	-0.186	-0.069	0.07	0.058	0.114	0.111	-0.085	-0.129	0.079	0.074	**-.207***	1		
R13	-0.031	**-.228***	0.078	0.006	0.12	**.220***	-0.056	-0.03	**-.227***	**-.318****	**-.713****	0.17	1	
R14	0.098	-0.109	0.126	-0.017	.234*	0.046	0	0.027	0.02	-0.027	-0.035	0.084	0.115	1

*Correlation is significant at the 0.05 level; **Correlation is significant at the 0.01 level
R1-Leaf colour R2-Crown shape R3-Flower composition R4-Inflorescence shape R5-Fruit shape R6-Rind colour R7-Spine texture R8-Spine colour R9-Aril colour R10-Aril taste R11-Aril texture R12-Aril juiciness R13-Adherence of aril to seed R14-Seed shape.

(0.497), rind weight (0.332), fruit length (0.326), fruit diameter (0.286), seed weight (0.298) and rind thickness (0.264). These results confirms the findings of Hiranpradit *et al*. (3) that fruit size (weight, width, length, thickness), rind weight and thickness, aril weight and thickness and seed weight are highly associated with fruit yield.

Fruit weight expressed high significant positive correlations with aril weight (0.864), rind weight (0.837), seed length (0.699), fruit length (0.694), fruit yield (0.654), fruit diameter (0.636), aril thickness (0.627), seed weight (0.449) and aril weight had got high significant positive correlations with fruit weight (0.864), aril thickness (0.728) and seed length (0.530).

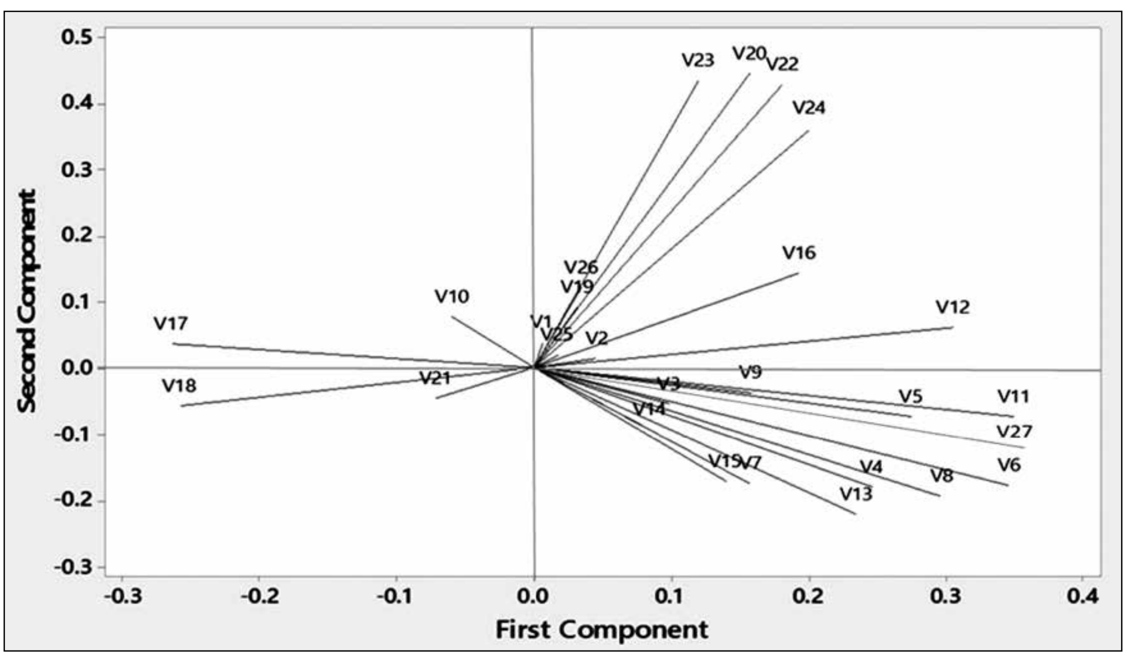

Fig. 1. Loading plot of tree characters based on first two principal components.

Table 2. Correlations among quantitative traits of rambutan.

	X1	X2	X3	X4	X5	X6	X7	X8	X10	X11	X12	X13	X15	X16	X17	X19
X3	-0.092	0.193	1													**.326(**)**.
X4	-0.055	0.096	**.420(**)**	1												.286(**)
X5	-0.04	**.213(*)**	**.694(**)**	**.636(**)**	1											.654(**)
X6	-0.093	**.254(*)**	**.436(**)**	**.303(**)**	**.435(**)**	1										.264(**)
X7	-0.083	**.250(*)**	**.651(**)**	**.523(**)**	**.837(**)**	**.541(**)**	1									.332(**)
X8	**-.255(*)**	-0.036	**.222(*)**	**.387(**)**	**.366(**)**	-0.007	**.222(*)**	1								0.127
X9	0.021	-0.106	**-.305(**)**	-0.079	-0.179	-0.061	-0.198	**.293(**)**								-0.042
X10	-0.091	0.172	**.504(**)**	**.690(**)**	**.864(**)**	**.264(**)**	**.717(**)**	**.341(**)**	1							.497(**)
X11	-0.065	**.207(*)**	**.333(**)**	**.487(**)**	**.627(**)**	**.253(*)**	**.457(**)**	**.303(**)**	**.728(**)**	1						0.169
X12	0.098	0.168	**.639(**)**	**.377(**)**	**.699(**)**	**.300(**)**	**.611(**)**	**.281(**)**	**.530(**)**	**.323(**)**	1					0.127
X13	**.261(**)**	-0.032	-0.024	**.312(**)**	**.215(*)**	0.097	0.075	0.162	**.250(*)**	**.237(*)**	**.267(**)**	1				0.076
X14	0.117	0.041	**.232(*)**	**.468(**)**	**.449(**)**	0.15	**.327(**)**	**.255(*)**	**.378(**)**	**.240(*)**	**.513(**)**	**.667(**)**				.298(**)
X15	0.119	0.036	0.048	0.178	0.092	-0.04	0.026	0.061	0.194	**.346(**)**	-0.011	-0.019	1			0.021
X16	0.105	0.057	0.096	**.214(*)**	0.17	0.019	0.112	0.081	**.247(*)**	**.390(**)**	0.02	0.022	**.946(**)**	1		0.084
X17	0.115	0.026	0.005	0.143	0.012	-0.09	-0.04	0.055	0.129	**.239(*)**	-0.041	-0.08	**.937(**)**	**.885(**)**	1	0.004
X18	0.083	0.072	0.15	**.235(*)**	**.262(**)**	0.097	**.208(*)**	0.088	**.298(**)**	**.444(**)**	0.062	0.095	**.812(**)**	**.937(**)**	**.667(**)**	0.132
X19	-0.02	0.132	**.326(**)**	**.286(**)**	**.654(**)**	**.264(**)**	**.332(**)**	0.127	**.497(**)**	0.169	0.127	0.076	0.021	0.084	0.004	**1**

*Correlation is significant at the 0.05 level **Correlation is significant at the 0.01 level

X1-Petiole length X2- No. of fruits per bunch X3- Fruit length X4- Fruit diameter X5- Fruit weight X6- Rind thickness X7- Rind weight X8- Spine length X9- Spine density X10- Aril weight X11- Aril thickness X12- Seed length X13- Seed width X14- Seed weight X15--TSS X16- Total Sugar X17 Reducing Sugar X18- Non reducing sugar X19-Yield

Spine length showed significant positive correlation with aril weight (0.341), aril thickness (0.303), seed length (0.281), seed weight (0.252) and rind weight (0.222) whereas it had significant negative correlation with petiole length (-0.255).

It was observed that total soluble solids had got very high significant positive correlations with total sugar (0.946), reducing sugar (0.937) and non-reducing sugar (0.812) whereas there was no correlation among TSS, ascorbic acid and total carotenoids. The loading plot drawn with first two principal components of fruit and quality characters also showed strong positive associations between reducing sugar, total soluble solids, total sugar and non-reducing sugar; fruit yield fruit weight, fruit diameter, rind weight, spine length, aril weight and aril thickness; seed weight, seed length and seed width as indicated by the acute angles between their vectors. The angle of approximate 180° between the vectors revealed a negative correlation between acidity and TSS (Fig. 2).

The highest positive direct effect on fruit yield was exhibited by fruit weight (0.569), aril weight (0.539) and its correlation with fruit yield was also positive which reveals true relationship between them and direct selection for this trait will be rewarding for yield improvement (Fig. 3). Seed weight showed high and positive direct effect on fruit yield (0.323) and its correlation with fruit weight was also positive.

Aril weight showed moderate positive and indirect effect on fruit weight (0.275) through the negligible and positive direct effect of fruit length (0.061) and expressed high positive and indirect effect on fruit weight (0.377) through the negligible positive and direct effect of fruit diameter (0.020).

The correlation studies using the above statistical tools can be interpreted as follows.

Correlation matrix formed with the qualitative traits revealed that the collections having soft textured aril exhibited very strong adherence of aril to seed whereas the collections having crispy aril were of free seed aril as indicated by the high negative correlation between aril texture and aril adherence (-0.713). A critical look at the development of the aril revealed that it is the inner tissue of the aril that firmly adheres to the seed coat imparting the strong binding and not the softness or firmness which makes it free stone (detachable) or cling stone types (non-detachable). The taste sweetness found to tend towards soft textured and creamy white aril, but moved away from free seed aril. The rachis length has got significant positive correlation with spine length which in turn positively correlated with fruit weight, aril weight and aril thickness, the characters

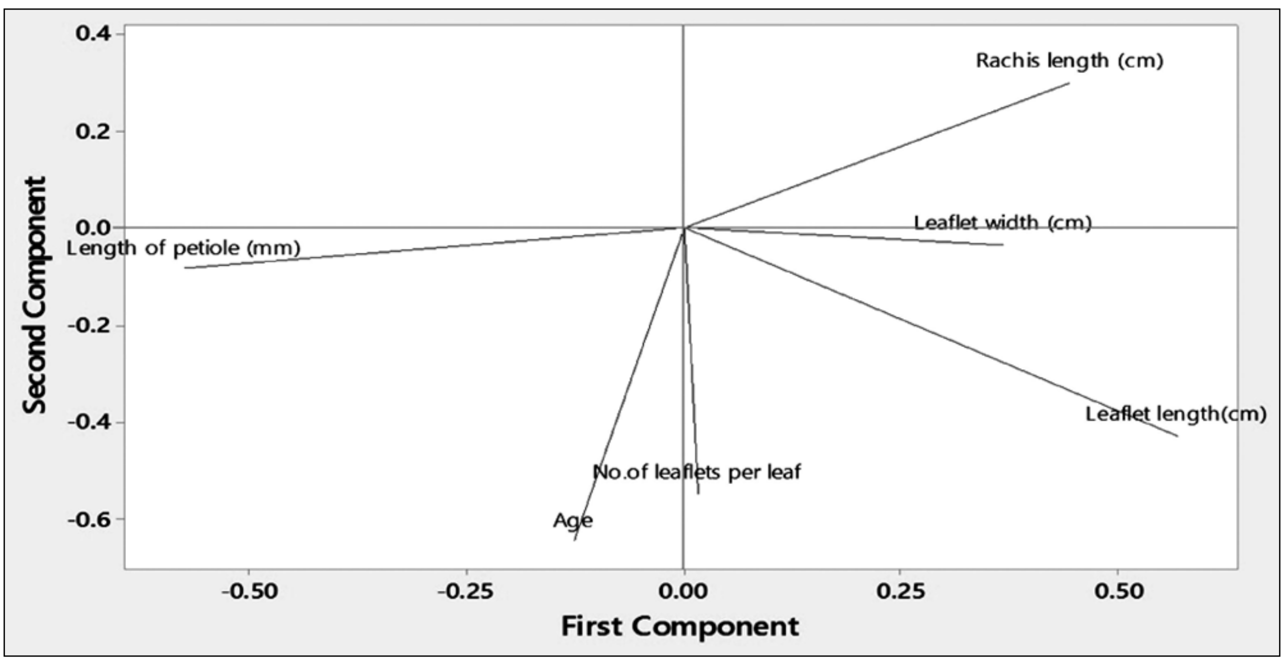

Fig. 2. Loading plot of fruit characters based on first two principal components.

V1-percentage fruit set, V2-length of fruit bunch, V3-number of fruits per bunch, V4-fruit length, V5-fruit diameter, V6-fruit weight, V7-rind thickness, V8-rind weight, V9-spine length, V10-spine density, V11-aril weight, V12-aril thickness, V13-seed length, V14-seed width, V15-seed weight, V16-aril to fruit ratio, V17-seed to fruit ratio, V18-seed to aril ratio, V19-shelf life, V20-TSS, V21-titrable acidity, V22- total sugar, V23-reducing sugar, V24-non-reducing sugar, V25-total carotenoids, V26-ascorbic acid, V27-fruit yield

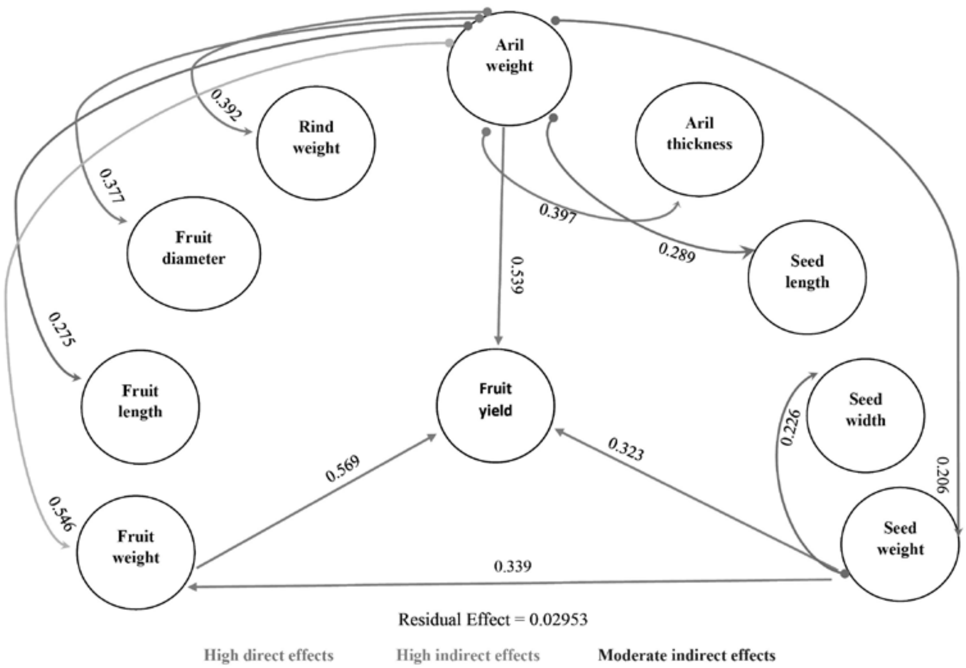

Fig. 3. Path diagram showing the significant direct and indirect effects on fruit yield of rambutan.

or traits of paramount importance. Further, the rachis length which influenced the fruit weight expressed strong association with leaflet width and leaflet length. The direct negative effect of petiole length on spine length influences both aril weight, fruit weight and yield indirectly. The works done by Barreto *et al*. (1) on morphological characterization of rambutan plants to verify whether it is possible to differentiate rambutan trees in the early stages of development even when they have not produced flowers and/ or fruits or in the nursery stage as reported in several fruit trees like purple passion fruit and carambola. They inferred that use of morphological characters of tree including foliar aspects is efficient in cataloguing the genetic variability between rambutan plants, but visual distinction is not possible, since no outstanding characteristic exists that helps to differentiate plants. Our results also support these findings. The high significant correlations of fruit yield with fruit weight, aril weight, rind weight, seed length, fruit length, fruit diameter, aril thickness, seed weight and rind thickness confirms the findings of Hiranpradit *et al*. (3) that fruit size (width, length, thickness), rind weight and thickness, aril weight and thickness and seed weight are highly associated with fruit weight.

Besides these, the correlation studies among the biochemical characters concluded that there is very high significant positive correlation among total soluble solids, total sugar, reducing sugar and non-reducing sugar and no correlation among TSS, ascorbic acid and total carotenoids which are in harmony with the findings of Wall *et al*. (11).

In this study the association of various quantitative as well as qualitative characters of rambutan was studied which gave information on the nature and relationship among various traits. The direct and indirect effect of component characters on fruit weight was also explained. These informations on extent of relationship and the interrelationship among the different traits can certainly supplement the crop improvement studies in rambutan by exploitation of various traits.

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