POPULATION STRUCTURE OF TAGNANAN COCONUT (*COCOS NUCIFERA L.*) AND CORRELATION AMONG FRUIT YIELD AND QUALITY TRAITS

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ABSTRACT

MATAG is one of Malaysia's widely cultivated coconut hybrids for its high fruit yield and quality traits, utilized in various food and nutraceutical products. It is obtained from the cross between Tagnanan, a tall-type coconut, with Malayan dwarf coconut varieties. The low success rate and inconsistencies in MATAG hybrid production were possibly due to the condition of Tagnanan as the pollen source, as tall-type coconuts are generally allogamous, making them heterogeneous. The study was conducted to obtain the phenotypic data on yield and fruit quality to describe the population structure and relationship among traits of the Tagnanan population at DOA, Teluk Bharu, Perak. One hundred palm of 12 years old were selected as representative of the whole Tagnanan population, where phenotypic and fruit quality data were collected. Generally, the Tagnanan population was divided into six clusters. Cluster 4, with 67% of the sample population, performed best in terms of meat weight and fruit yield. Cluster 3 grouped individuals with high shell weight and shell and copra thickness. Correlation analysis shows a strong positive relationship between fruit weight, nut weight, split nut weight and most fruit quality traits. However, a negative correlation existed between copra thickness and shell thickness. Clustering of individuals in the sample population of Tagnanan based on their phenotypic performance is an essential step in identifying and selecting groups with high fruit yield and quality. Understanding the relationship among fruit quality components enables the estimation of correlated responses in selecting these traits. Selection of these individuals based on their cluster allows the improvement of the Tagnanan population by only harvesting nuts from these clusters to form the new population as a pollen source for Matag hybrid production.

Keywords: *Cluster analysis, Coconut, Correlation, Tagnanan.*

INTRODUCTION

Coconut is Malaysia's fourth most important industrial crop after oil palm, rubber, and rice (Tan, 2019). It originated in South-East Asia's coastal nations and is widely distributed and cultivated in the tropics and sub-tropics (Hoe, 2018). The global coconut production was put at 61.9 million metric tons in 2020 (FAO, 2020), with Asia producing the most, with nations including the Philippines, Indonesia, and India accounting for 75% of global production. Malaysia produced 538,685 mt of coconuts in 2018 on a total coconut-planting area of 81,585 ha (Omar et al., 2020).

Among the coconut types planted in Malaysia include Tagnanan, a tall coconut variety that is naturally cross-pollinating and heterozygous. It can grow to 20-30m tall and matures slowly, producing 10,000 nuts/ha/year. It has big fruit, a thick trunk, big bole at the base with large crowns (Batugal & Bourdeix, 2005). Tagnanan is also used as the pollen source in a cross with Malayan

Yellow Dwarf/Malayan Red Dwarf (MYD/MRD), producing a hybrid called F_1 Matag. This hybrid has a yield potential of up to 30,000 nuts/ha/year with good fruit and meat yield as Tagnanan, and it has a shorter stature similar to the Malayan dwarf (Hoe, 2018). Matag has thicker flesh, producing a much heavier copra than other varieties.

One of Matag's hybrid production Centre's is mainly maintained in Teluk Bharu, Perak, where pollen is tested, collected and preserved to pollinate with MYD/MRD population. The variability of fruit types and colour observed (Figure 1) led to inconsistencies in Matag production and performance. There is a need to select individuals with high yield and fruit quality from the currently heterogeneous population. It can be achieved by obtaining phenotypic data on the fruit quality of the population to determine groups or clusters.

Figure 1: Showing the tagnanan variations base on colour.

A **B** **C**

A = Tagnanan Red/Orange; **B** = Tagnanan Gold; and **C** = Tagnanan Green (Hijau)

Based on similarities, hierarchical cluster analysis (HCA) groups data samples within one cluster and classifies them from samples of other clusters (Amit et al., 2022). The unweighted pair-group arithmetic average method (UPGMA) establishes relationships among accessions by producing a dendrogram using the Euclidean distance scale based on similarity and relatedness. The closer the relationship between the various components under evaluation, the smaller the Euclidean distance between them (Siregar et al., 2019). The clustering of individuals in a certain population indicates variation for the characters observed and measured, thus conforming to the heterogeneity of the population. Identifying clusters with high yielding and high quality, Tagnanan can help in the selection procedure and ultimately improve the population mean.

Correlation coefficients reveal an association among the traits that contribute to yield. Selecting suitable genotypes depends on the association between yield and yield-attributing characteristics (Maheswarappa & Rajkumar, 2021). Additionally, correlation analysis shows the linear relationship between the measured variables (Zhang et al., 2021). Correlation coefficient values close to 1 or -1 indicate a strong and significant relationship between variables. Individuals that belong to the same cluster based on their performance also substantiate the relationship revealed by correlation among traits in a population. The study aimed to group and select individuals with robust fruit yield and quality attributes related to food production and determine the correlation relationships among the observed variables in a Tagnanan population.

MATERIAL AND METHODS

The materials used for this study were the Tagnanan coconut population (Green, Gold, and Red) cultivated and maintained as one of the main pollen sources for Matag hybrid production at the Department of Agriculture (DOA) station in Teluk Bharu, Perak. The sampled palm's pollen was continually used in the production of Matag. Hence, the pollen was chosen primarily based on fruit quality and colour. One hundred individuals out of 321 palms were randomly selected for the study. Growth indicators measured include trunk circumference at 20cm and 150cm from the base and the height of the palm at the 11th leaf scar from the same base. Fruit quality traits include the number of fruit yields, fruit size, fruit weight, nut weight, the weight of split nut, meat weight, shell weight, husk weight, the volume of water, shell thickness, copra thickness, and dry matter content.

DATA ANALYSIS

The quantitative and qualitative data observed and measured were processed and analysed. NTSYS-pc 2.1 software using the Unweighted Pair Group Average Method (UPGMA) algorithm. SAHN methods were used to illustrate the dendrogram of genetic association among the Tagnanan variations based on the coefficient of a similarity distance. The software program RStudio version 4.2.2 was used to compute correlation analysis to determine the relationship between variables.

RESULT AND DISCUSSIONS

CLUSTERING OF TAGNANAN INDIVIDUALS BASED ON FRUIT YIELD AND QUALITY

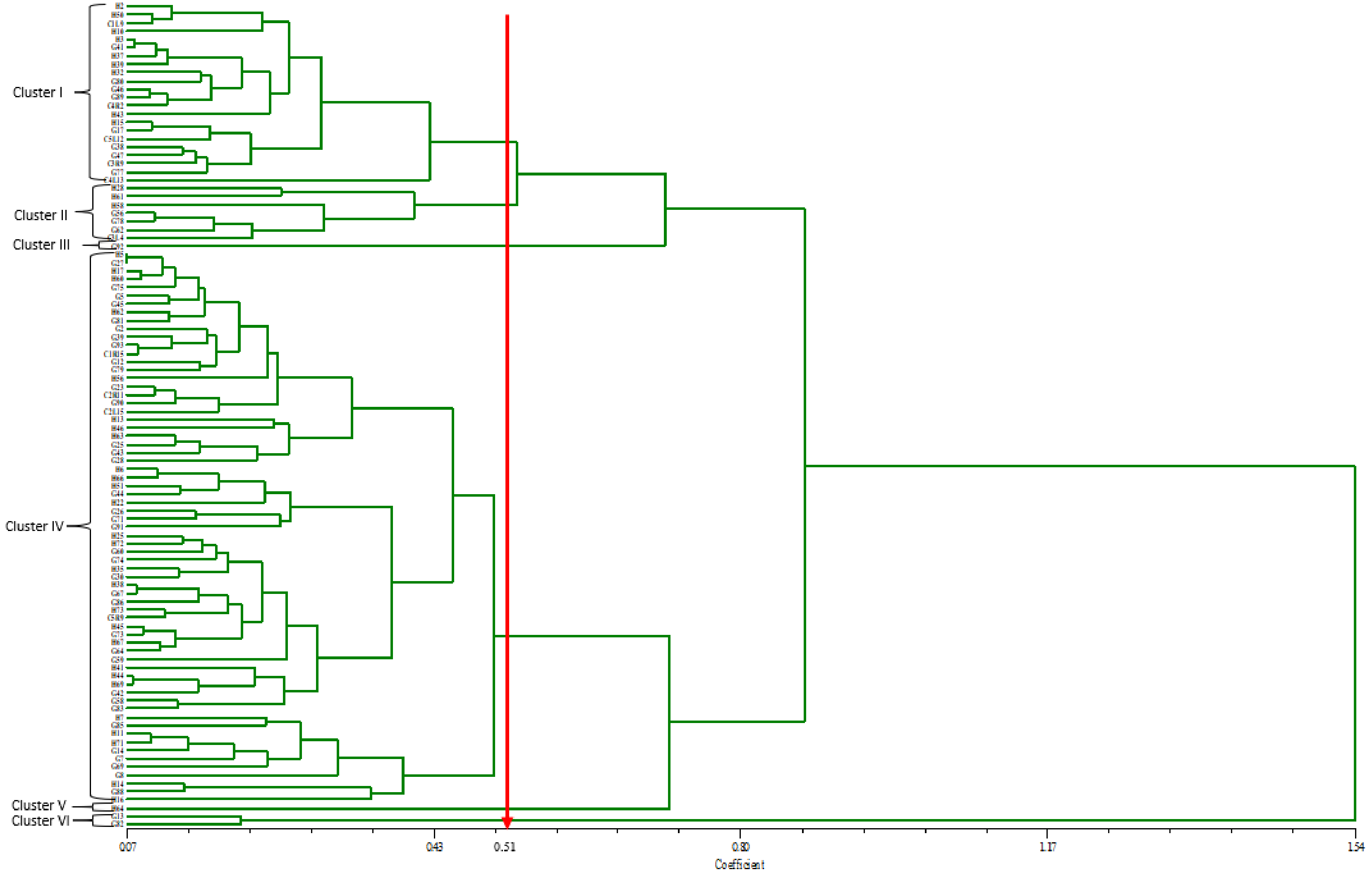
A dendrogram constructed using corresponding similarity coefficients from UPGMA analysis was used to determine the clustering pattern among the palms in the sample population. The dendrogram grouped the 100 palms into six major significant clusters at 0.51 coefficient based on trait similarity (Fig. 2). This shows diversity among palms within the Tagnanan population. The smaller the Euclidean distance between the several objects analysed, the closer the relation of the object and the more similarity the character possessed (Siregar et al., 2019).

Table 1 lists all the palms in their respective cluster. Cluster 1 includes 22 palms with the second-highest mean fruit size value and average means of fruit yield components (Table 2). In Cluster 3, the single palm's (G92) unique traits were for the trunk circumference at 150cm from the base, shell weight, shell thickness, and copra thickness. Compared to other clusters, these had the highest mean value (Table 2). Further, it showed the second highest mean values for traits such as fruit yield, fruit weight, nut weight, the weight of split nut, and volume of water.

Cluster 4, which had the highest number of 67 palms (Table 1), was the best-performing group among all the clusters. It consists all the Tagnanan fruit colours in the population with the highest mean value recorded for meat weight (Table 2). It indicated that those palms might be from the same progenitor (Nartvaranant, 2019). However, members of this group had the lowest mean value for the number of fruit yields per palm.

This variation is also observed in this Tagnanan population, as shown by the clustering analysis. The pollen of the sampled palms was the one frequently used for Matag production. Although the choice of pollen was mainly based on the fruit colour, selection based on fruit quality need to be considered as well (Sankaran et al., 2012).

Figure 2. Phenetic tree dendrogram using the Euclidean distances for 100 Tagnanan palms



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TYPES BASED ON FRUIT COLOUR: G = Gold; H = Green (Hijau); CRL = Red (Orange

Table 1: List of Tagnanan palm per cluster according to morphological and fruit quality

Cluster 1	Cluster 2	Cluster 3	Cluster 4			Cluster 5	Cluster 6
H2	H28	G92	H5	G43	G64	H64	G13
H50	H61		G27	G28	G59		G82
C1L9	H58		H17	H6	H41		
H10	G56		H60	H66	H44		
H32	G78		G75	H51	H69		
G80	G62		G5	G44	G42		
G46	C3L4		G45	H22	G58		
G89			H62	G26	G83		
C4R2			G81	G71	H7		
G26			G2	G91	G85		
G71			G39	H25	H11		
H3			G93	H72	H71		
G41			C1R15	G60	G14		
H37			G12	G74	G7		
H39			G79	H35	G69		
H15			H56	G30	G8		
G17			G23	H38	H14		
G38			C2R11	G67	G88		
G47			G90	G86	H16		
C3R9			C2L15	H73			
G77			H13	C5R9			
C5L12			H46	H45			
H43			H63	G73			
C4L13			G25	H67			
22	**7**	**1**		**67**		**1**	**2**

Note: **G** = Gold Tagnanan; **H** = Green (Hijau) Tagnanan; **CRL** = Red (Orange) Tagnanan

Table 2: Cluster mean values with ranking of six clusters for all traits among 100 Tagnanan coconut

Morphological traits	Cluster I	Cluster II	Cluster III	Cluster IV	Cluster V	Cluster VI
20cm (cm)	193.51 (5)	208.27 (2)	189.80 (6)	205.47 (3)	204.50 (4)	226.55 (1)
150cm (cm)	92.74 (5)	97.19 (4)	108.20 (1)	98.78 (3)	62.10 (6)	104.80 (2)
11sc (cm)	68.53 (3)	62.41 (5)	59.90 (6)	67.80 (4)	69.80 (2)	71.45 (1)
Fruit yield (no.)	7.70 (5)	8.33 (3)	9.00 (2)	6.63 (6)	11.33 (1)	8.33 (4)
Fruit size (cm)	42.35 (2)	35.21 (4)	33.10 (5)	36.43 (3)	24.50 (6)	63.70 (1)
Fruit weight (g)	1902.36 (4)	1971.71 (3)	2209.00 (2)	1639.81 (5)	733.00 (6)	3531.50 (1)
Nut weight (g)	1132.91 (4)	1007.14 (5)	1245.00 (2)	1191.72 (3)	517.00 (6)	1479.00 (1)
Weight of split nut (g)	743.59 (4)	682.29 (5)	824.00 (2)	782.15 (3)	402.00 (6)	827.00 (1)
Meat weight (g)	486.27 (3)	423.57 (4)	252.00 (6)	526.46 (1)	292.00 (5)	497.50 (2)
Shell weight (g)	256.50 (5)	258.71 (3)	572.00 (1)	257.03 (4)	110.00 (6)	329.50 (2)
Husk weight (g)	769.45 (4)	964.57 (2)	964.00 (3)	448.09 (5)	216.00 (6)	2052.50 (1)
Volume of water (cm^3)	389.32 (4)	324.86 (5)	421.00 (2)	409.57 (3)	115.00 (6)	652.00 (1)
Shell thickness (mm)	4.37 (4)	4.42 (3)	5.27 (1)	4.32 (5)	3.95 (6)	4.97 (2)
Copra thickness (mm)	11.17 (3)	10.55 (5)	11.98 (1)	11.39 (2)	11.17 (4)	8.55 (6)
Dry matter content (%)	9.15 (4)	9.24 (3)	8.73 (6)	8.98 (5)	10.51 (2)	13.25 (1)

NB: Numbers in parenthesis signify the ranking among clusters for every trait measured.

Key: **20cm** = bole circumference at 20cm from the base; **150cm** = circumference at 150cm from the ground; **11sc** = height at the 11^{th} leaf scar from the bottom.

CORRELATION ANALYSIS AMONG TRAITS RELATED TO FRUIT YIELD AND QUALITY

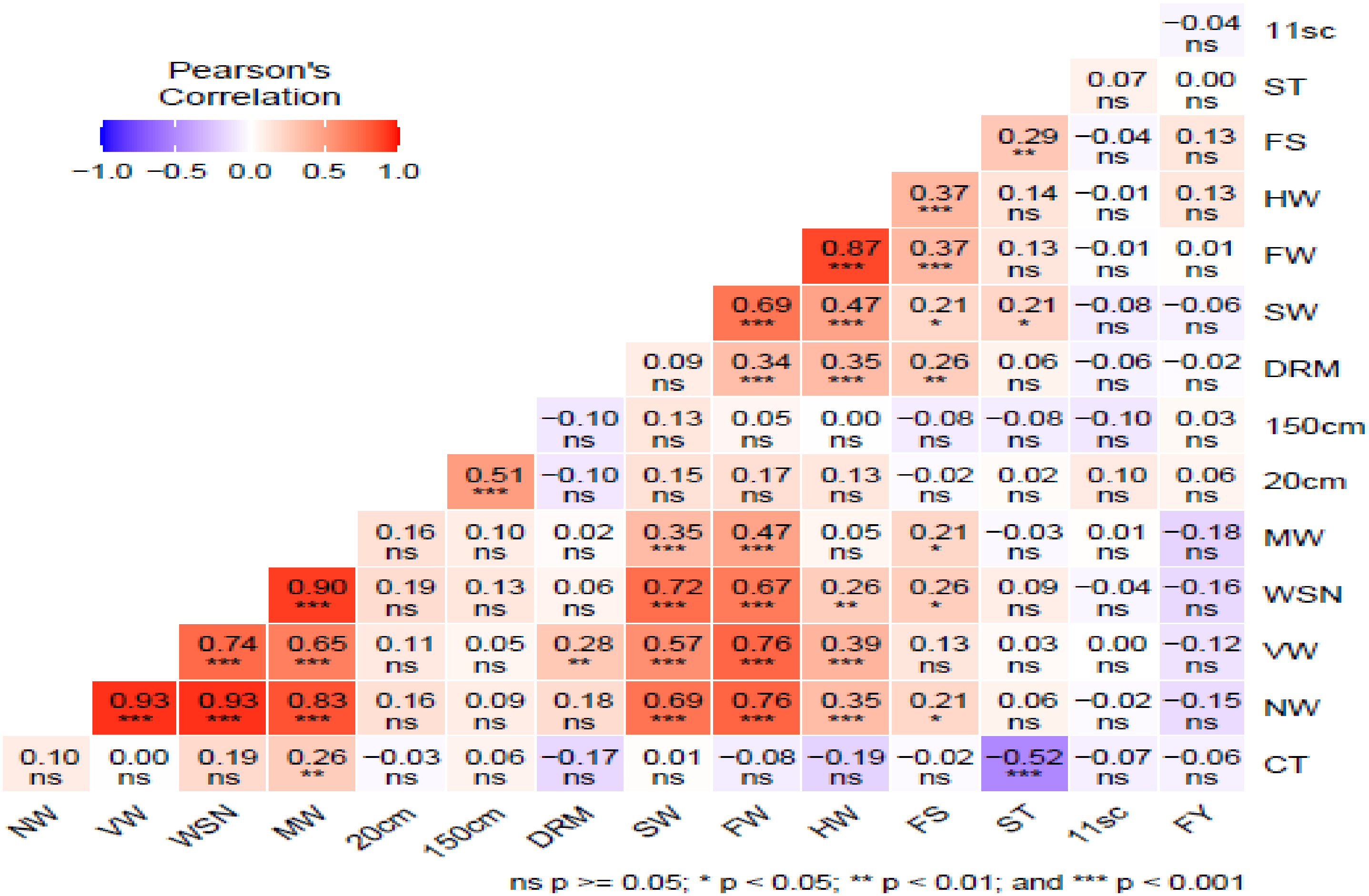
The correlation analysis of fruit morphology and quality traits among 100 Tagnanan coconuts are shown in (Fig. 3). Correlation coefficients close to 1 or -1 generally indicate a significant and strong association between variables Schober & Schwarte (2018). A positive correlation at ($p<0.05$) was shown between fruit weight and nut weight (0.76), water volume (0.76), the weight of split nut (0.67), and shell weight (0.69). Nut weight was strongly and positively correlated with meat weight (0.83), the weight of split nut (0.93), and the volume of water (0.93), and it was positively correlated with shell weight (0.69) and fruit weight (0.76). It explained that the higher the weight of the split nut, the higher the weight of meat, shell, and volume of water. The positive association revealed that traits could be selected primarily for fruit yield and food qualities such as meat weight and volume of water. It also indicates that the correlated traits should improve as one trait is improved (Odufale et al., 2022).

Similarly, the weight of the split nut was strongly and positively correlated with meat weight (0.90), shell weight (0.72) and fruit weight (0.67). There was a negative correlation between copra thickness and shell thickness (-0.52). The thickness of copra increases with a decrease in the shell thickness and vice versa. Fruit component traits like meat weight, husk weight, and water volume will all be higher on palms with higher fruit weights. The result is in tandem with the findings of Zizumbo-Villarreal & Piñero (1998) and Ranasinghe & Premasiri (2016). They revealed that varieties of coconut that have fewer branches per palm with more fruits could, over time, produce more coconut meat and copra per palm than cultivars that have more branches with fewer fruits. Similar findings of a significant positive correlation between copra yield and most fruit component parameters were also reported by Maheswarappa & Rajkumar (2021). There is a positive correlation due to the interdependence of different fruit components, which tend to vary in the same direction (Baudouin et al., 2006). It serves as selection criteria for breeders to choose for their traits of interest as they are the significant component of yield in coconut (Odufale et al., 2022). Although there was a weak association between fruit size and husk weight (0.37) and fruit weight (0.37), Daa-Kpode et al. (2021) found that the larger the fruit, the heavier and more substantial the shell.

The trunk circumference measured at 20cm from the base is positively correlated with that measured at 150cm (0.51) from the same base. It shows a putative growth pattern of the trunk height and bole enlargement related to each other. For growth traits, most of the negative correlations were not significant. According to Maheswarappa & Rajkumar (2021), an increase in nut production correlates negatively with copra thickness. They further indicated that as the number of nuts increased, the competition to assimilate among the growing nuts in each bunch could lead to thinner copra.

It was also revealed by Geethanjali et al. (2014) that fruit traits components were positively correlated, but they showed a significant negative correlation with the number of nuts produced per palm per annum. No correlations existed between the number of fruit yields and other fruit component traits. It is in line with the findings of Perera et al. (2015), who reported that fruit yield has no significant correlation with other fruit component traits. Therefore, the number of fruit yield cannot be chosen as a predictor for selecting fruit trait components as exhibited by the correlation.

Fig. 3: Correlation analysis of fruit morphology and quality traits of 100 Tagnanan coconut sample population



Key: **20cm = bole circumference at 20cm from the base; 150cm = circumference at 150cm from the ground; 11sc = height at the 11th leaf scar from the bottom; FY = fruit yield; FW = Fruit weight; NW = Nut weight; WSN = weight of split nut; SW = Shell weight; MW = Meat weight; ST = Shell thickness; CT = Copra thickness; FS = Fruit size; DRM = Dry matter content; VW = volume of water; HW = Husk weight.**

CONCLUSION

The cluster analysis showed evident similarities and differences among the Tagnanan population. The individuals were grouped into clusters with high fruit yield quality attributes and food production attributes that can be selected as pollen and seed sources to generate a new Tagnanan population. Palms from cluster IV, which had the best performance for most fruit yield and quality traits, could be selected for future Tagnanan establishment. Correlation analysis revealed that nut weight is strongly and positively correlated with meat weight, fruit size, water volume, and split nut weight. This study showed morphological differences among Tagnanan palms, even those of the same fruit colour, emphasizing that the selection approach for pollen source should be based on these characters and not by fruit colour alone. It could also improve the selection of the Tagnanan population towards producing high-quality Matag. Future research is recommended to explore molecular approaches to establish the relationship between the two techniques and further validate the findings of this research.

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