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Promising Novel Coconut Hybrids (TxT and DxT) with Ayiramkachi as a Common Parent

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Authors' contributions

This work was carried out in collaboration between both authors. Author RS designed and supervised the study. Author CG conducted the experiments, performed the analysis, and wrote the manuscript. Both authors read and approved the final manuscript.

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ABSTRACT

Hybridization is a key strategy for improving coconut (*Cocos nucifera* L.) productivity. However, the genetic potential of indigenous semi-tall varieties remains largely unexplored. This study evaluated nine novel F1 hybrids developed using the semi-tall genotype 'Ayiramkachi' (AYK) as a common parent to identify elite combinations with high yield and desirable agronomic traits. The hybrids, along with their parents, were evaluated from 2021 to 2023 for vegetative, reproductive, yield, and quality parameters. Significant variation (P<0.05) was observed for all traits. The hybrid Laccadive Micro x Ayiramkachi (LM x AYK) was the most outstanding, recording the highest annual nut yield (101.5 nuts/palm). For quality traits, Philippines x Ayiramkachi (PHI x AYK) yielded the highest copra content (218.96 g/nut), while West Coast Tall x Ayiramkachi (WCT x AYK) showed the highest oil content (68.5%). Conversely, the hybrid AYK x Malayan Yellow Dwarf (AYK x MYD) was the poorest performer in terms of both yield and quality. The study identifies LM x AYK as a promising candidate for commercial cultivation due to its superior

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nut yield and semi-dwarf stature, demonstrating the high utility of 'Ayiramkachi' as a parent for transmitting high female flower production and moderate palm height in coconut breeding programmes.

Keywords: Coconut; Ayiramkachi; hybrid evaluation; Dwarf x Tall hybrids; Tall x Tall hybrids; copra content; oil content; genetic improvement.

1. INTRODUCTION

Coconut (*Cocos nucifera* L.), a perennial monocot, the sole species in the genus *Cocos,* family Arecaceae, is referred to as "tree of life," accounting for its multifaceted uses in various sectors like food, oil, fiber, and other industrial uses and provides a stable backbone for the farmers. The palm is an economically important crop widely cultivated in the tropical region. Globally, coconut is cultivated in more than 90 countries, expanding in an area of around 12 million hectares, with an annual production of 62 million tonnes of nuts (FAO, 2022). India ranks third in coconut production, after Indonesia and the Philippines. It is cultivated in an area of around 2.1 million hectares and annual nut production of around 20 billion nuts (CDB, 2021). In India, the states Kerala, Tamil Nadu, and Karnataka account for more than 90% of coconut cultivation. The importance and value of the coconut in Kerala can be very well understood from Kerala being referred to as 'land of coconuts'.

The palm, though, served as a staple income-generating source for years, there is a declining trend in cultivation and productivity recently. The major reasons can be attributed to rise in the cost of cultivation, lack of skilled labourers, labor-intensive management and harvesting, severe attacks of pests and diseases coupled with difficulty in crop protection activities, lower prices for the primary products like nut, oil and copra, long juvenile phase etc.

However presently there is a positive change in global coconut sector due to the increasing demand of various value added products and nutraceuticals developed from coconut. Hence there is an urgent need to focus on the trait-specific coconut improvement. This has led to lay focus on improvement of quality also rather than just the quantity. Today's breeding approaches thus aim at trait-based breeding, suitable for enhancing the nutritional quality of the end product. In this context, genetic improvement through hybridization has been used to enhance the productivity and quality in coconut.

The tall coconut varieties are heterozygous with a cross-pollinating nature, while the dwarf palms are self-pollinating in nature. Hybrid vigor in coconut was first reported in India (Patel, 1937) in a cross between WCT x CGD. Ayiramkachi is a semi-tall variety, characterised by medium stature, early flowering and numerous female flowers. The name 'Ayiramkachi' literally translates to 'thousand nuts', reflecting its high nut yield, though the actual yield is 150-400 nuts per palm. However, Ayiramkachi produced smaller-sized nuts, and the nut weight as well as copra weight were less. This cultivar was reported to be suitable for use in a hybridization program, as it is an intermediate between tall and dwarf types.

The long juvenile phase and tall stature of traditional varieties pose significant challenges to profitability in coconut cultivation. While Dwarf x Tall hybrids have proven effective, the genetic diversity of parental lines remains limited. The indigenous semi-tall variety 'Ayiramkachi' offers a unique combination of high female flower production and intermediate stature. Therefore, the primary objective of this study was to evaluate the *per se* performance of nine novel F1 hybrids developed using 'Ayiramkachi' as a common parent, to identify elite combinations with high nut yield, superior copra and oil content, and reduced palm stature suitable for modern, high-density cultivation systems.

2. MATERIALS AND METHODS

2.1 Plant Material and Experimental Site

The research was carried out from 2021 to 2023 under Coconut Mission, College of Agriculture, Padannakkad and Regional Agricultural Research Station (RARS), Piliocde; two major coconut research stations in Kasaragod districts of Kerala under the Kerala Agricultural University, Kerala, India. The materials consisted of nine coconut hybrid combinations of Ayiramkachi, as a common parent. All the parental palms (Table 1) are from the germplasm collection maintained at RARS Pilicode. The hybrid combinations included Philippines x

Ayiramkachi (PHI x AYK), Cochin China x Ayiramkachi (CC x AYK), Laccadive Ordinary x Ayiramkachi (LO x AYK), West Coast Tall x Ayiramkachi (WCT x AYK), Andaman Ordinary x Ayiramkachi (AO x AYK), Laccadive Micro x Ayiramkachi (LM x AYK), Ayiramkachi x West Coast Tall (AYK x WCT), Malayan Yellow Dwarf x Ayiramkachi (MYD x AYK) and Ayiramkachi x Malayan Yellow Dwarf (AYK x MYD). The hybrids were planted in 1994 at the RARS, Pilicode. The first flowering of these hybrids was observed in 2000. The hybrids were maintained under rainfed conditions with a spacing of 7.5 m x 7.5 m at the RARS, Pilicode, following the recommended Package of Practices of Kerala Agricultural University (KAU, 2011).

2.2 Data Collection on Vegetative and Reproductive Traits

Data on a comprehensive set of morphological characters were recorded (Tables 2 & 3). Vegetative traits like height, trunk girth, petiole length and leaf length were recorded once in an year. Reproductive traits like the number of female flowers produced per inflorescence, number of female flowers retained after one month of pollination, total number of inflorescences in the crown, and the number of new inflorescences produced were recorded on monthly basis. Yield traits such as number of bunches per palm per year, number of nuts produced per bunch and number of nuts produced per palm per year were recorded during harvest, average six harvests per year. For recording the nut characters and assessing the quality of nuts, five mature nuts, 11 to 12 months old, were collected from each palm, and the various nut characters were recorded (Tables 4 & 5).

2.3 Nut Component and Quality Analysis

For copra analysis, five mature nuts per palm were de-husked and the fresh kernel (endosperm) was weighed. The kernel was then sliced and dried in a hot air oven at 65°C until a constant weight was achieved (approximately 6% moisture content). The final dry weight was recorded as the copra content per nut (g). Oil content was estimated from dried, powdered copra using a Soxhlet extraction apparatus with petroleum ether (boiling range 60-80°C) as the solvent. The oil content was expressed as a percentage of the dry copra weight. Total phenolic content in the kernel was determined using the Folin-Ciocalteu method. Methanolic extract of the fresh kernel was mixed with Folin-Ciocalteu reagent and sodium carbonate solution. After incubation in the dark, the absorbance was measured at 765 nm using a spectrophotometer. A standard curve was prepared using gallic acid, and the results were expressed as mg of gallic acid equivalents per gram of fresh weight (mg GAE/100g).

Table 1. Characteristics of parental genotypes used in the hybridization

Parent Name	Abbreviation	Type	Origin / Source	Key Reported Characteristics
Ayiramkachi	AYK	Semi-tall to tall	Found in coastal regions of Tamil Nadu, and Kerala, India	Early flowering, high female flower count (profuse bearing), small-sized nuts (Sankaran et al 2015)
West Coast Tall	WCT	Tall	Indigenous (West Coast, India)	High copra and oil content, adaptable, late bearing, tall stature (Ratnambal, 2001)
Malayan Yellow Dwarf	MYD	Dwarf	Exotic (Malaysia)	Early bearing, high nut number, small nuts, susceptible to drought (Ratnambal, 2001)
Laccadive Ordinary	LO	Tall	Indigenous (Lakshadweep, India)	High copra content, medium-large nuts, regular bearer (Ratnambal, 2001)
Laccadive Micro	LM	Tall	Indigenous (Lakshadweep, India)	High nut yield, small nuts (Ratnambal, 2001)
Philippines Ordinary	PHI	Tall	Exotic (Philippines)	Large nuts, long petiole (Ratnambal, 2001)

Parent Name	Abbreviation	Type	Origin / Source	Key Reported Characteristics
Andaman Ordinary	AO	Tall	Indigenous (A&N Islands, India)	High nut yield, adapted to island ecosystems (Ratnambal, 2001)
Cochin China	CC	Tall	Exotic	Large, round nuts, high copra content, dual-purpose variety (Ratnambal, 2001)

2.4 Statistical Analysis

The mean values were calculated for each trait and subjected to statistical analysis to determine the significance of differences among the hybrid combinations. The mean values of all the traits were subjected to Analysis of Variance (ANOVA) as proposed by Panse and Sukhatme (1985). The statistical analysis was performed using GRAPES software version 1.0.0. (Gopinath *et al*., 2020).

3. RESULTS AND DISCUSSION

The research involved the assessment of a diverse set of coconut hybrids developed using 'Ayiramkachi' as a common parent. Various parameters, including growth rate, flowering patterns, and nut production, were monitored to understand the hybrids' overall performance. Moreover, copra content and oil content were estimated and the biochemical analysis for total phenols and fatty acid profiling also were carried out to determine the quantity and quality of the kernel for each hybrid. Preliminary findings indicate significant variability in copra and oil yield among the coconut hybrids under investigation. Certain hybrids demonstrated exceptional potential for high copra and oil production, suggesting their suitability for commercial cultivation. Also nut water is an important by product of copra industry which now is used for making diverse value-added products like *nata-de-coco*, processed & packed coconut water drink, vinegar etc. The nut water content and TSS give an indication about suitable varieties for these purposes.

3.1 Vegetative Growth Parameters and Dwarfing Nature of the Hybrids

The morphological characters of the nine combination of coconut hybrids developed using Ayiramkachi as the common parent with several tall and dwarf genotypes were used in the study. The hybrids developed were found to be significantly different for all the characters studied. The mean values are provided in Table 2.

Reduced palm height is a highly desirable character as far as coconut farmers are concerned due to easiness in crop management and crop protection activities as well as during harvest. Ayiramkachi is classified as medium tall to tall and in the present study it is crossed with different tall cultivars (T x T) as well as dwarf (T x D and its reciprocal).

Palm height varied significantly across genotypes under evaluation. Among the tall parents, height ranged from 9.89 m (PHI) to 17.90 m (WCT), while for the dwarf parent (MYD) it was only 5.76m. Most hybrids displayed reduced height compared to tall parents and was on par with the hybrid used as check viz., Kerasree (WCT x MYD). The height of hybrids (TxT) produced by crossing Ayiramkachi (10.24m) with other talls ranged from 5.98m (PHI x AYK) to 10.18 m (LO × AYK), whereas the hybrids produced by crossing MYD with AYK (including the reciprocal) were shorter (5.62 m and 7.32m). An important observation is that the cross PHI x AYK though a T x T, was exhibiting dwarf character which is on par with the dwarf palm MYD. This may be due to the fact though PHI is classified as tall, the height was only 9.89 m and hence this is also a promising genotype to develop dwarf palms.

Girth of the palm at 20 cm and 1.5m height are usually measured to distinguish between talls and dwarfs based on the presence or absence of swelling at the basal region of the trunk called bole. In talls there is a bowl at the base, while in the dwarfs it is absent (Sudha *et al*., 2021). Girth at 20 cm was lowest in both hybrids with MYD as one of the parent, resembling the dwarf parent nature, while WCT × AYK showed the highest value, on par with tall parent WCT, indicating the bole formation in the hybrid resembling the parent WCT. AYK do not show a prominent bole as in other talls.

Table 2. Vegetative characters of Ayiramkachi hybrids with parents and check variety Kerasree

Genotypes	Height (m)	Girth of the palm at 20 cm (cm)	Girth of the palm at 1.5 m (cm)	Ratio of Girth at 20 cm to Girth at 1.5 m (cm)	Internode length (cm)	Petiole length (cm)	Leaf length (cm)
PHI x AYK	5.98^{g}	108.20^{ef}	77.08^{efg}	1.40^{cde}	4.30^{de}	127.20^{bcde}	485.00^{ab}
CC x AYK	7.79^{ef}	106.00^{efg}	75.50^{fgh}	1.40^{ce}	4.80^{cd}	143.00^{a}	493.25^{ab}
LO x AYK	10.18^{cd}	103.50^{efg}	80.00^{cdefg}	1.29^{defg}	6.95^{a}	130.00^{abcd}	497.50^{ab}
WCT x AYK	7.50^{efg}	127.00^{cde}	84.00^{bcdef}	1.51^{abcd}	6.90^{ab}	128.00^{abcde}	452.00^{b}
AO x AYK	8.60^{def}	126.50^{cde}	82.00^{cdef}	1.54^{abc}	6.33^{ab}	116.50^{cde}	477.50^{ab}
LM x AYK	8.64^{cdef}	125.50^{cde}	84.50^{bcde}	1.48^{bcd}	5.30^{bcd}	136.00^{ab}	447.50^{b}
MYD x AYK	7.32^{fg}	90.33^{g}	67.00^{i}	1.35^{def}	4.27^{de}	130.00^{abcd}	456.00^{b}
AYK x WCT	8.72^{cdef}	101.50^{efg}	76.00^{efgh}	1.34^{defg}	6.40^{ab}	132.50^{abc}	527.50^{a}
AYK x MYD	5.62^{g}	94.00^{fg}	70.00^{ghi}	1.34^{defg}	4.00^{def}	98.00^{e}	352.00^{c}
AYK	10.24^{c}	99.00^{fg}	68.00^{hi}	1.46^{bcd}	3.50^{ef}	123.00^{bcde}	350.00^{c}
LM	12.75^{b}	136.00^{bc}	92.00^{ab}	1.48^{bcd}	5.30^{bcd}	126.00^{bcde}	517.00^{a}
LO	12.50^{b}	112.00^{def}	88.00^{abc}	1.27^{efg}	4.70^{cde}	130.00^{abcd}	495.00^{ab}
AO	13.21^{b}	128.00^{cd}	86.00^{bcd}	1.49^{bcd}	5.70^{abc}	126.00^{bcde}	517.00^{a}
CC	10.25^{c}	98.00^{fg}	79.00^{defg}	1.24^{fg}	5.60^{abc}	126.00^{bcde}	517.00^{a}
PHI	9.89^{cd}	149.00^{ab}	95.00^{a}	1.57^{ab}	5.50^{bc}	125.00^{bcde}	528.00^{a}
WCT	17.90^{a}	156.00^{a}	94.00^{a}	1.66^{a}	6.70^{ab}	108.00^{e}	365.00^{c}
MYD	5.76^{g}	63.00^{h}	57.00^{j}	1.11^{g}	2.90^{f}	110.00^{de}	366.00^{c}
KS	9.15^{cde}	96.00^{fg}	78.00^{efg}	1.23^{fg}	3.60^{ef}	109.00^{e}	443.00^{b}
Mean	9.62	112.45	79.66	1.40	5.05	124.24	465.08
SE (m)	0.55	6.53	2.75	0.06	0.42	6.24	20.44
CV	9.82	10.05	5.98	7.27	14.50	8.71	7.612
CD	1.92	23.00	9.68	0.17	1.49	22.00	72.05

In the genotypes evaluated, girth of the palm at 20 cm height above ground differ significantly among the genotypes. The girth of the palm at 20 cm height ranged from 63.00 cm (MYD) to 156.00 cm (WCT) among parents, and from 94.00 cm (AYK x MYD) to 127.00 cm (WCT x AYK) among the hybrids. The check variety Kerasree was having a value of 96.00 cm for the character girth of palm at 20 cm height.

Trunk girth in palms is also often correlated with plant vigour and productivity. Patil *et al*. (1993) reported that high nut yields were associated with increased stem circumference, short-spaced petioles and broad leaflets. Usually in dwarfs the trunk will be thinner than tall as is seen in the present study also (57.00cm in MYD). The ratio between the trunk girth at 20cm height and 1,65m height indicate that for the dwarf palm MYD the trunk is almost of same girth (ratio 1.1) at base and at 1.5m height, while in hybrids and tall parents there is swelling at the base. The check Kerasree, which also is a hybrid of MYD (WCT x MYD) has lesser swelling at the base (ratio 1.2). In the remaining hybrids it was less than or equal to that of the tall parents.

Short internodes are characteristic of dwarfs (2.90 cm in MYD) giving it a compact appearance. Among the hybrids, the two hybrids from crossing AYK with MYD and PHI x AYK exhibited lowest values for internode length indicating a dwarfing nature compared to the rest of the hybrids.

A healthy palm produces a leaf per month, and a spadix arises from each functional leaf. Thus, the number of functional leaves present in a palm indicates the health and productivity of a palm. Among the hybrids, leaf number was highest in CC × AYK (25.58) closely followed by the hybrids from LO, LM and WCT and lowest in AYK × MYD. A high rate of leaf production during the early growth phase has positive correlation with the early flowering, nut yield and copra yield, which can serve as an indicator for predicting the yield potential of hybrids (Liyanage *et al*., 1988). Leaf length and petiole length, important characters that determine the ability of the leaf to support the bunches and influence the photosynthetic efficiency, showed significant variation among the genotypes for petiole length and leaf length.

The results from the study affirm the well-established principle that vegetative vigor is often a prerequisite for high productivity in coconut. The highest-yielding hybrid, LM x AYK, also exhibited a superior rate of leaf production and a robust stem girth, whereas the low-yielding AYK x MYD was inferior for these vegetative traits. The ability to identify and cull poor-performing genotypes at the nursery stage would dramatically increase the efficiency and reduce the cost of coconut breeding programmes, which are otherwise hampered by the crop's long generation time.

3.2 Yield Potential of the Hybrids

Significant genetic variation (P<0.05) was observed among the hybrids for all inflorescence and yield component traits (Table 3). Floral traits are key determinants of nut yield in coconut, as each inflorescence represents a direct unit of reproductive potential. Once a palm reaches the bearing stage, each newly formed leaf is accompanied by an inflorescence. The hybrids evaluated in the present study exhibited Significant genetic variation (P<0.05) in inflorescence characters, particularly in the number of female flowers per inflorescence.

The number of inflorescences is highest for LM x AYK (15.14), followed by hybrids from CC (13.98), LO (13.15) and WCT (13.72), while the lowest in AYK x MYD (9.33). This is in consensus with the number of green functional leaves in these hybrids indicating the significance of the leaf number in a palm. This is the reason why the leaf number in early vegetative growth phase in seedlings also is used for selection programmes in coconut. The same pattern is observed for the rate of inflorescence production as indicated by the number of unopened inflorescences per month.

The significance of female flower production in yield determination has been recognized since the initial studies on heterosis in coconut. Patel (1938) emphasized that the proportion of nuts harvested in relation to the number of female flowers is the most critical criterion for assessing yield potential. Subsequently, Kannan and Nambiar (1974) demonstrated that high-yielding hybrids generally possess a greater number of female flowers. This fundamental relationship has been further substantiated by numerous recent reports (Ranasinghe et al., 2015; Kanimozhi, 2018; Suchithra and Paramaguru, 2019; Sivakumar et al., 2024). In the present study, the highest number of female flowers per inflorescence was recorded in WCT × AYK, while the lowest was observed in AYK × MYD. Hybrid with AYK as the male parent (MYD x AYK) produced more female flowers per inflorescence, whereas its reciprocal cross produced fewer, indicating the influence of parental combinations (Zadjehi *et al*., 2019). Setting percent of female flowers was calculated by counting the number of female flowers retained on the inflorescence one month after pollination as against the total female flowers produced in it. The hybrid LM x AYK showed the highest percentage (58.87%), followed by MYD x AYK and CC x AYK. In the hybrid AYK x MYD, though setting percentage is higher, the total number of female flowers is less, which in turn reduces the total yield (Table 3, Fig. 1).

Annual nut yield displayed significant variation, with LM x AYK producing an average of 101.50 nuts per palm per year followed by the hybrids from LO, CC and MYD with AYK. Among these MYD x AYK is a dwarf palm compared to other hybrids and with highest number of nuts per bunch (10.72) and good yield (94.56). The hybrids PHI x AYK and AYK x MYD also exhibited dwarfing nature, but nut yield per bunch as well as total nuts per palm per year were the lowest. Number of bunches per palm did not differ significantly among the hybrids, suggesting that this trait may be relatively stable and less influenced by genetic background compared to flower number or nuts per bunch. These results reaffirm that yield in coconut is a cumulative expression of several floral and fruit traits, where higher numbers of female flowers and improved nut retention after pollination directly translate into better productivity. The commercial value of superior hybrids is influenced by their increased copra output, higher nut set per bunch, and more female blooms (Foale, 2003).

3.3 Morphological Traits and Quality of the Nuts from Hybrids

The fruit characters like size and weight of the nut, quantity and quality of nut water, copra, oil and phenol content of the kernel indicated significant variability among the hybrids (Tables 4 & 5).

Among the hybrids the highest yielding hybrid LM x AYK have big sized nuts weighing 1.35Kg, husked nut weight 0.56Kg and thick kernel (1.33cm). The hybrid PHI x AYK though a poor yielder, is the best performer with respect to most of the superior nut characters. It has the biggest nuts, each unhusked nut weighing more than one kilogram (1.41kg), husked nut weight 0.75Kg and highest shell and meat weight (551.44g), quantity of liquid endosperm (174.48ml), copra content (218.96g) and oil content (66.72%). This is a promising combination as usually dwarf genotypes have thin meat and lower copra and oil content when compared to tall varieties (Suchithra & Paramgaru, 2019).

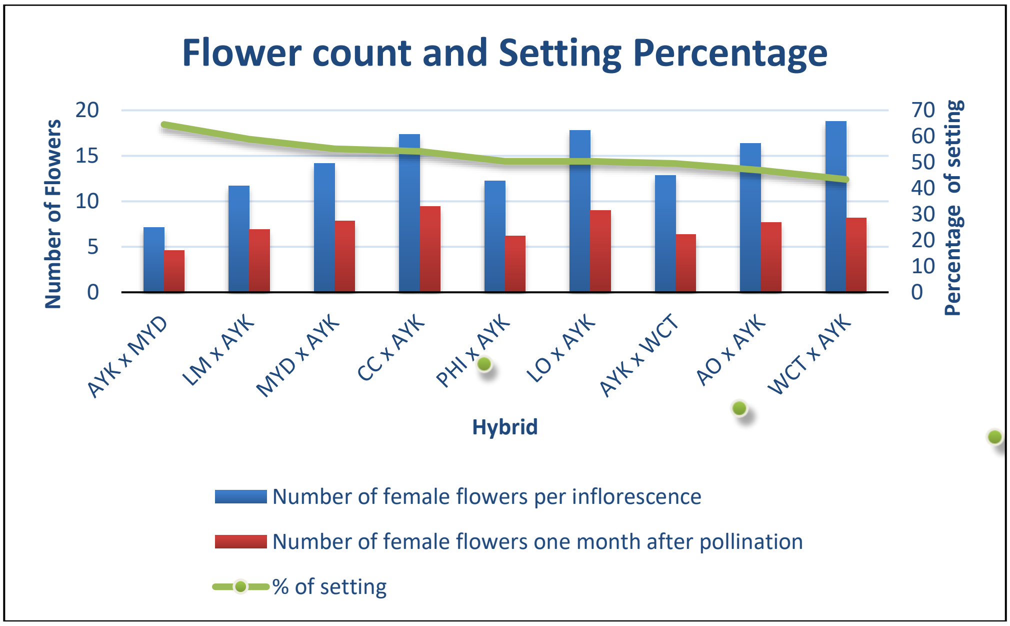

Fig. 1. Comparison of female flower production and setting percentage among nine hybrids of Ayiramkachi

Table 3. Mean performance for reproductive characters of coconut hybrids of Ayiramkachi

Hybrid	Total number of inflorescences in crown at the time of observation	Number of unopened inflorescences	Number of new inflorescences	Number of female flowers per inflorescence	Number of female flowers one month after pollination	Number of nuts per palm per year	Number of nuts per bunch	Number of bunches per palm	Number of Green leaves	Rate of leaf production
PHI x AYK	11.60 ^{de}	2.05 ^{a}	5.60 ^{ab}	12.23 ^{bcd}	6.170 ^{cd}	37.80 ^{c}	4.37 ^{d}	7.67	22.24 ^{cde}	1.16
CC x AYK	13.98 ^{ab}	2.09 ^{a}	6.75 ^{a}	17.37 ^{abc}	9.42 ^{a}	92.00 ^{ab}	9.55 ^{abc}	9.25	25.58 ^{a}	1.14
LO x AYK	13.15 ^{bcd}	2.16 ^{a}	6.17 ^{ab}	17.81 ^{ab}	8.98 ^{ab}	95.67 ^{a}	9.86 ^{ab}	9.50	24.74 ^{ab}	1.13
WCT x AYK	13.72 ^{abc}	2.19 ^{a}	6.67 ^{ab}	18.79 ^{a}	8.16 ^{abc}	71.00 ^{abc}	7.21 ^{abcd}	9.33	23.72 ^{abc}	1.11
AO x AYK	12.01 ^{cde}	2.09 ^{a}	5.58 ^{ab}	16.35 ^{abc}	7.67 ^{abc}	45.83 ^{bc}	6.58 ^{bcd}	6.00	20.63 ^{e}	1.10
LM x AYK	15.14 ^{a}	2.24 ^{a}	6.67 ^{ab}	11.72 ^{cd}	6.90 ^{abcd}	101.50 ^{a}	8.85 ^{abc}	11.17	24.18 ^{ab}	1.24
MYD x AYK	11.20 ^{e}	2.06 ^{a}	5.44 ^{ab}	14.16 ^{abc}	7.82 ^{abc}	94.56 ^{a}	10.72 ^{a}	8.45	22.91 ^{bcd}	1.11
AYK x WCT	11.19 ^{e}	2.20 ^{a}	5.17 ^{bc}	12.85 ^{bc}	6.36 ^{bcd}	57.00 ^{abc}	6.89 ^{bcd}	8.17	21.42 ^{de}	1.10
AYK x MYD	9.33 ^{f}	1.26 ^{b}	3.67 ^{c}	7.11 ^{d}	4.59 ^{d}	44.67 ^{c}	6.03 ^{cd}	7.33	17.78 ^{f}	1.03
Mean	12.37	2.04	5.75	14.26	7.34	71.11	7.78	8.54	22.58	1.12
SE(m)	0.59	0.15	0.53	1.89	0.92	15.51	1.18	1.16	0.62	0.04
CD	1.77	0.46	1.58	5.66	2.74	46.50	3.54	NS	1.87	NS
CV	8.27	13.11	15.84	22.91	21.58	37.77	26.26	23.54	4.79	6.58

Table 4. Mean performance for nut characters of coconut hybrids of Ayiramkachi

Genotype	Size of unhusked nut (equatorial) (cm)	Size of unhusked nut (pole to pole) (cm)	Fruit weight (g)	Nut weight (g)	Shell and meat weight (g)	Quantity of liquid endosperm (ml)	Sugar Content (Bx)	Kernel Thickness (cm)
PHI x AYK	54.60 ^{ab}	58.85 ^{abc}	1405.56 ^{ab}	746.56 ^{b}	551.44 ^{b}	174.48 ^{bc}	4.22 ^{cd}	1.24 ^{cd}
CC x AYK	49.70 ^{cd}	58.71 ^{abcd}	1108.80 ^{cde}	649.20 ^{bcd}	496.75 ^{bcd}	143.90 ^{cde}	4.69 ^{bc}	1.34 ^{ab}
LO x AYK	41.58 ^{efg}	51.85 ^{fg}	931.70 ^{e}	420.00 ^{ef}	354.10 ^{fg}	60.20 ^{f}	5.39 ^{ab}	1.33 ^{abc}
WCT x AYK	51.00 ^{bcd}	55.74 ^{cdefg}	1170.20 ^{bcde}	455.20 ^{ef}	388.00 ^{efg}	68.20 ^{f}	5.90 ^{a}	1.26 ^{abd}
AO x AYK	39.62 ^{g}	52.19 ^{fg}	872.50 ^{e}	464.70 ^{ef}	385.45 ^{fg}	74.95 ^{f}	4.42 ^{cd}	1.33 ^{abc}
LM x AYK	53.04 ^{abc}	62.05 ^{ab}	1354.00 ^{abc}	562.70 ^{cde}	461.20 ^{cdef}	91.60 ^{ef}	4.29 ^{cd}	1.33 ^{abc}
MYD x AYK	43.37 ^{deefg}	52.51 ^{efg}	801.47 ^{e}	424.93 ^{ef}	354.27 ^{fg}	55.73 ^{f}	4.73 ^{abc}	1.25 ^{abcd}
AYK x WCT	41.88 ^{efg}	51.64 ^{fg}	940.90 ^{e}	376.10 ^{f}	313.50 ^{g}	52.10 ^{f}	5.72 ^{a}	1.32 ^{abc}
AYK x MYD	37.46 ^{g}	47.74 ^{g}	856.20 ^{e}	405.60 ^{f}	320.00 ^{g}	62.20 ^{f}	5.64 ^{ab}	1.42 ^{a}
AYK	40.78 ^{fg}	50.22 ^{g}	1003.60 ^{de}	409.40 ^{f}	326.80 ^{g}	78.80 ^{f}	4.60 ^{bc}	1.12 ^{d}
LM	44.70 ^{def}	55.90 ^{cdef}	1091.40 ^{cde}	411.80 ^{f}	338.40 ^{g}	69.20 ^{f}	4.46 ^{cd}	1.24 ^{bcd}
LO	44.42 ^{defg}	55.74 ^{cdefg}	1161.20 ^{cde}	461.00 ^{ef}	368.60 ^{fg}	88.60 ^{f}	4.28 ^{cd}	1.30 ^{abc}

Genotype	Size of unhusked nut (equatorial) (cm)	Size of unhusked nut (pole to pole) (cm)	Fruit weight (g)	Nut weight (g)	Shell and meat weight (g)	Quantity of liquid endosperm (ml)	Sugar Content (Bx)	Kernel Thickness (cm)
AO	56.62 [a]	62.82 [a]	1520.00 [a]	959.20 [a]	701.20	237.80 [a]	4.44 [cd]	1.40 [a]
CC	47.10 [cde]	57.68 [bcde]	1029.00 [de]	698.00 [bc]	504.40 [bc]	188.40 [bc]	3.88 [d]	1.28 [abc]
PHI	49.84 [cd]	58.31 [abcd]	1120.40 [cde]	632.60 [cd]	469.20 [cde]	153.20 [cd]	3.84 [d]	1.32 [abc]
WCT	43.24 [defg]	55.46 [cdefg]	1122.60 [cde]	533.00 [de]	399.00 [efg]	131.60 [de]	4.66 [bc]	1.24 [bcd]
MYD	51.24 [bc]	61.70 [ab]	1205.80 [bcd]	655.60 [bc]	424.20 [def]	210.00 [ab]	4.04 [cd]	1.10 [d]
KS	43.30 [defg]	53.88 [defg]	967.80 [e]	484.60 [ef]	396.60 [efg]	81.00 [f]	4.22 [cd]	1.22 [cd]
Mean	46.78	56.36	1115.16	569.10	434.15	125.31	4.44	1.27
S.E. (m)	1.62	1.61	78.04	38.69	26.25	14.82	0.24	0.04
C.V.	7.76	6.39	15.65	15.20	13.52	26.45	11.91	5.93
C.D.	4.61	4.57	221.56	109.85	74.52	42.08	0.67	0.10

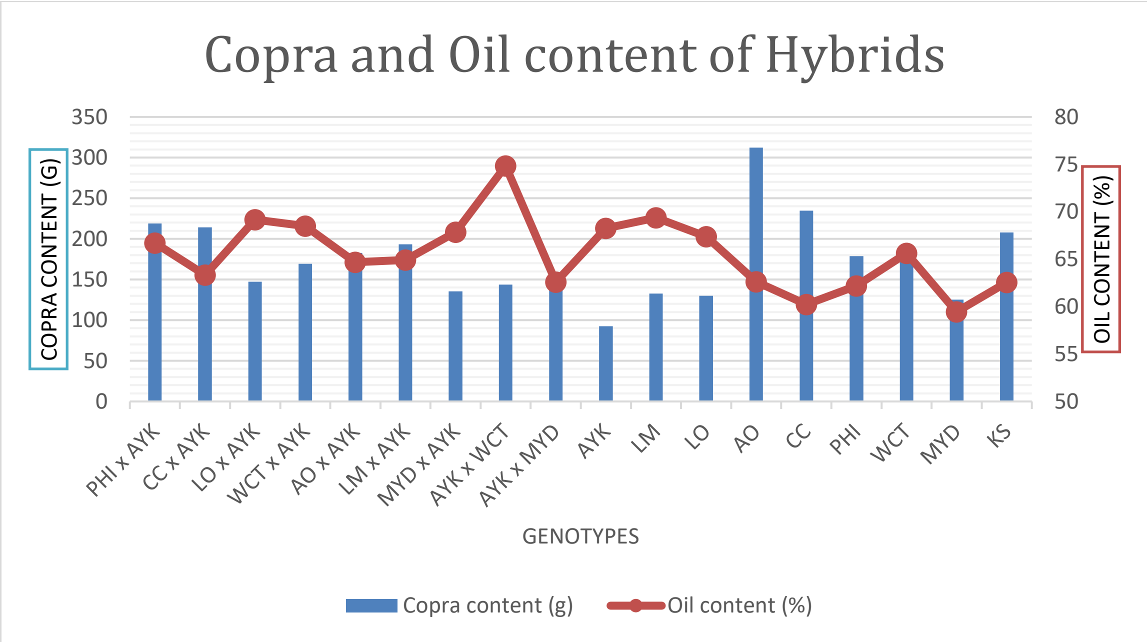

Fig. 2. Mean copra and oil content of different coconut genotypes

The nut water in hybrid WCT x AYK and its reciprocal cross was sweet, with sugar contents of 5.90 and 5.74 ºBx, respectively. Another interesting observation is that the copra from these two hybrids has high oil content, at 68.50 percent in WCT x AYK and 74.83 percent in AYK x WCT, which are the highest among all hybrids and parents (Tables 5, Fig. 2). This may be because among the cultivars, WCT has the best-quality copra and oil. Oil content is always an important trait when evaluating coconut genotypes, as it is the most economically significant product in the market. However, the WCT x AYK hybrid yields only moderately, while the reciprocal hybrid performs poorly in yield.

Coconut accessions have wide variability among them for fruit component traits (Niral *et al*., 2009). Modern coconut breeding targets market needs, such as high copra and oil content or tender nut quality. However, there is an opportunity to breed for value-added biochemical traits like phenols, which are natural antioxidants that improve product stability and health benefits. The identification of the hybrid CC x AYK, with its exceptionally high total phenol content (75.167 mg GAE/g), demonstrates this potential. This finding opens the possibility of developing specialized hybrids with specific biochemical profiles for premium markets, such as functional foods and virgin coconut oil (VCO).

The superior performance of the hybrid combination LM x AYK for most morphological and yield characters, including high fruit weight, nut weight and copra content, indicates its potential as a promising hybrid for commercial cultivation. This finding is consistent with previous research works in which tall x dwarfs were identified as high-yielding (Parthasarathy *et al.,* 1998). The poor performance of the hybrid AYK x MYD for traits like fruit weight and oil content suggests a less effective combination of parental genes. The use of 'Ayiramkachi', a semi-tall variety, as a common parent offers a more nuanced modulation of palm height in the F1 generation, as evidenced by the fact that most hybrids were significantly shorter than their tall parents yet generally taller than pure dwarfs. A key finding is the superior performance of hybrids where 'Ayiramkachi' was used as the pollen parent (e.g., WCT x AYK, LM x AYK) in terms of female flower production. The results highlight a strong paternal effect from 'Ayiramkachi', but only in specific combinations. This contrasts with a parent's more general, average performance. The poor results of the AYK x MYD cross demonstrate that identifying parental pairs is the most critical factor in developing superior hybrids.

The hybrid PHI x AYK produced the highest copra per nut (218.96 g) but had the lowest annual nut yield (37.8 nuts). Conversely, MYD x AYK had the highest number of nuts per bunch (10.7) but a much lower copra content (135.6 g). This inverse relationship between nut number and individual nut size/copra content is a well-documented phenomenon in coconut breeding. The standout performance of LM x AYK, which balances a high nut number (101.5) with respectable copra content (193.2 g), suggests it has a more optimal partitioning of resources, making it a superior selection for overall productivity (Odufale *et al.,* 2022).

Table 5. Biochemical characters of coconut hybrids of Ayiramkachi in comparison with parental cultivars and check palm

Genotype	Copra content (g)	Oil content (%)	Total Phenol Content (mg/ GAE)
PHI x AYK	218.96 bc	66.72 bcd	64.60 cd
CC x AYK	214.30 bcd	63.33 de	75.17 abc
LO x AYK	147.40 fghi	69.18 abc	66.16 cd
WCT x AYK	169.20 efgh	68.50 abcd	65.61 cd
AO x AYK	182.80 cdef	64.69 cde	65.74 cd
LM x AYK	193.20 bcdef	64.93 bcde	73.69 abcd
MYD x AYK	135.60 ghi	67.84 bcd	68.05 bcd
AYK x WCT	143.80 fghi	74.83 a	68.20 bcd
AYK x MYD	148.40 efghi	62.60 de	69.90 abcd
AYK	92.40 i	68.26 bcd	85.49 ab
LM	132.80 hi	69.37 ab	63.15 cd
LO	130.00 hi	67.38 bcd	64.74 cd
AO	312.40 a	62.61 de	89.37 a
CC	234.80 b	60.24 e	66.08 cd
PHI	178.80 defg	62.20 de	79.90 abc

Genotype	Copra content (g)	Oil content (%)	Total Phenol Content (mg/ GAE)
WCT	171.60 efg	65.61 bcd	54.58 d
MYD	125.20 hi	59.45 e	66.44 cd
KS	208.00 bcde	62.57 de	56.86 d
Mean	178.35	65.02	69.06
S.E. (m)	13.20	1.50	6.38
C.V.	16.54	5.16	15.99
C.D.	37.48	4.26	15.07

The results of this study provide valuable insights into the selection and breeding of coconut hybrids optimized for copra and oil production. This information is essential for coconut growers, agricultural researchers, and stakeholders in the coconut industry, as it can contribute to the development of sustainable coconut cultivation practices and the supply of high-quality coconut-based products to meet the growing global demand. Further research is recommended to fine-tune the cultivation techniques and validate the performance of the identified high-yielding coconut hybrids under different environmental conditions.

4. CONCLUSION

This study successfully evaluated nine novel coconut hybrids and identified the Tall x Tall cross, Laccadive Micro x Ayiramkachi (LM x AYK), as a superior genotype, demonstrating a high annual nut yield of 101.5 nuts/palm combined with a desirable semi-dwarf stature. The hybrid also had favorable growth characteristics like circular crown, bole formation, strong and long leaves and petioles. The hybrids CC x AYK and MYD x AYK also had superior performance, considering their annual nut and copra yield.

Hybrid Philippines x Ayiramkachi is a promising one with dwarf nature and superior nut characters and nut quality but since yield is compromised, the cultivar Philippines can be used as one of the parents to develop dwarf hybrids with high yield by crossing with other dwarf palms like CGD, COD or MYD as well as new cross with Ayiramkachi.

The results unequivocally highlight the significant potential of the indigenous tall variety ‘Ayiramkachi’ as a valuable genetic resource for imparting high female flower production and modulating palm height in hybridization programmes.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

During the preparation of this work the author(s) used OpenAI’s Google Gemini tool in order to improve the language and readability of the manuscript. The AI did not contribute to the original data analysis, interpretation, or the initial drafting of the manuscript's scientific content. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the publication.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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