STUDIES ON PER SE PERFORMANCE OF COCONUT HYBRIDS (*COCOS NUCIFERA* L.)

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Abstract. In coconut, commercial cultivation of hybrids is preferred due to earliness in flowering and increased yield with higher quantity and better quality of copra and oil content when compared to the varieties. In the present study, five coconut hybrid combinations namely Chowghat Orange Dwarf (COD) x Arasampatti Tall (ALR), Arasampatti Tall (ALR) x Malayan Green Dwarf (MGD), Malayan Green Dwarf (MGD) x Arasampatti Tall (ALR), Chowghat Orange Dwarf (COD) x West Coast Tall (WCT) and Kenthali Dwarf (KTD) x Arasampatti Tall (ALR) were evaluated, along with their parents and two tall varieties (West Coast Tall and Kalpatharu) serving as local checks. The study focused on evaluation of growth, yield and nut parameters at ICAR-AICRP (Indian Council of Agricultural Research – All India Coordinated Research Projects) on Palms centre, Coconut Research Station, Tamil Nadu Agricultural University, Aliyarnagar, Coimbatore district, Tamil Nadu, India. The experimental palms were planted in 2012 at a spacing of 7.5 × 7.5 m in a Randomized Block Design with four replications, consisting six palms per replication. The findings indicated that the coconut hybrid combination MGD x ALR exhibited precocity, with spathe emergence recorded within 34 months after planting followed by the hybrids COD x ALR, COD x WCT and KTD x ALR demonstrated similar patterns. The average performance over three years, the hybrid COD x ALR demonstrated superiority in the number of female flowers per bunch (21.4), nut yield (82.5 per palm per year) and copra yield (16.4 kg per palm per year). Simultaneously, the hybrids COD x WCT excelled in the attributes such as whole nut weight, de-husked nut weight and copra output per nut.
Keywords: *coconut breeding, hybrid evaluation, location specific crosses, quantitative traits, qualitative traits*

Introduction

Coconut (*Cocos nucifera* L.) is popularly termed as a "tree of heaven" due to its diverse economic uses and significance in sustaining people's livelihood. In India, coconut is cultivated in an area of 2,153.74 thousand hectares, with a total production of 19,309.90 million nuts and a productivity of 9966 nuts per hectare (CDB 2021-22). Tamil

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Nadu is one among the leading producers of coconuts in India, with 446.16 thousand hectares under cultivation, producing 5091.83 million nuts with a productivity of 11,413 nuts per ha (CDB 2021-22). Typically, tall coconut cultivars are utilized for copra and oil production, while dwarf cultivars are utilized for tender nut purposes. The characteristics such as perennial nature, very tall stature, long juvenile period, high level of outcrossing, heterozygosity, difficulties in clonal propagation, need for skilled person to perform essential operations like cleaning, thinning, harvesting and difficulty in recording of observations along with the requirement of large areas for performance assessment, present obstacles in coconut breeding program. Nevertheless, hybrids have their own advantages by expressing hybrid vigor. Among numerous breeding approaches, manipulation of hybrid vigor has the most significant impact on coconut improvement. As the desired characters such as high yield, precocity in bearing, excellent quality, high copra and oil content, and resistance to biotic and abiotic stresses, are distributed among different varieties or individuals of the same variety, hybridization stands out as the most useful tool to bring these desirable traits together (Ganesamurthy et al., 2004).

Hybrids show earliness in flowering and give increased yield, higher quantity and quality of copra and oil when compared to the parents. When the tall variety is used for hybridization with dwarf variety, the progenies are called T x D hybrids, while the reciprocal is known as D x T hybrids. Organized work on hybridization in India was initiated in 1930's by using West Coast Tall as a female parent and Chowghat Green Dwarf as the male parent. This is reflected to be one of the notable achievements in coconut breeding. Patel (1937) was the first to report about the hybrid vigor in coconut based on his Tall x Dwarf hybridization. An attempt was made to exploit heterosis in coconut, by making five cross combinations involving two tall varieties (Arasampatti Tall, West Coast Tall) and three dwarf varieties (Chowghat Orange Dwarf, Malayan Green Dwarf and Kenthali Dwarf). The developed hybrids and their parents were evaluated for their *per-se* performance along with two check varieties *viz*., West Coast Tall and Kalpatharu and the outcomes are discussed in this research article. The goal of this study was to identify a high performing coconut hybrid from the crosses planted in Coconut Research Station, Tamil Nadu Agricultural University, Aliyarnagar, Coimbatore district, Tamil Nadu, India based on the quantitative and qualitative traits.

Materials and methods

Five coconut hybrid combinations along with their parents and two tall varieties serving as local checks were evaluated under Indian Council of Agricultural Research-All India Co-ordinated Research Projects on Palms, Coconut Research Station, Tamil Nadu Agricultural University, Aliyarnagar, Coimbatore district, Tamil Nadu, India. This location is situated near the Western Ghats at 10° 29'N latitude, 76° 58'E longitude, with an elevation of 260 m MSL, featuring undulating topography. This region typically receives a total annual rainfall of 800 mm, with around 300 mm received during the south west monsoon, 330 mm during north east monsoon and 170 mm during summer. Maximum and minimum temperatures during summer and winter were 35°C and 22.1°C, 31.9°C and 16.8°C respectively. The soil is sandy loam, non-calcareous, with a neutral pH, low nitrogen, medium P_2O_5 and high K_2O content (Selvamani and Duraisami, 2014). The experimental material comprised five cross combinations, namely COD x ALR, ALR x MGD, MGD x ALR, COD x WCT and KTD x ALR along with their respective parents and two tall varieties, namely West

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Coast Tall and Kalpatharu, used as local checks (*Fig. 1*). Details of the parent varieties utilized for hybrid development are presented in *Table 1* and the crosses synthesized and utilized for the experiment are presented in *Table 2*.

View of the experimental plot

COD x ALR hybrid

KTD x ALR hybrid

MGD x ALR hybrid

Figure 1. *Experimental plot and material*

Table 1. *Details on parents and check varieties*

S. No.	Parents	Traits of parents	Accession number
1.	Chowghat Orange Dwarf	An early flowering dwarf genotype, typically initiating flowering 3 years after planting. Particularly well suited for tender nut water	IND 007
2.	Malayan Green Dwarf	A semi-tall variety known for its sweet tender nut water with more resistance to root wilt disease. It typically begins flowering 54 months after planting, yielding an average of 87 nuts per palm per year, 16.38 kg of copra per palm and 10.65 kg of oil per palm annual	IND 049
3.	Kenthali Dwarf	Dwarf variety renowned for its orange-colored nuts, primarily for tender nut purpose. The average yield is 86 nuts/palm/year with > 500 ml of tender nut water/nut. The tender nut water contains a superior quality of Total soluble solids: 5.2%, Rich in potassium: 190.2 mg per 100 g. This variety is tolerant to Eriophyid mite infestation	IND 074

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4.	Arasampatti Tall	Tall variety with average yield of 125 nuts/palm/year. The maximum potential nut yield is 183 nuts/palm/year. The yield increase of this variety over WCT, ECT and VPM 3 are 48%, 88% and 66% respectively. This variety has higher copra outrun of 5 kg copra/palm/year. Moderately resistance to basal stem rot, stem bleeding disease and bud rot	ALR
5.	West Coast Tall (Check variety)	A superior high yielding and early bearing tall variety, comes to flowering in 58 months. The average nut yield is 152 nuts per palm per year with estimated copra yield of 3.6 t/ha per year. Suitable both for rainfed and irrigated condition	IND 069
6.	Kalpatharu (Check variety)	This variety is suitable for ball copra production. It yields around 116 nuts per palm per year with copra content of 176 g, under rainfed cultivation. This is tolerant to drought	TPT

Table 2. *Details of hybrids and check varieties*

S. No.	Cross combination	Aim of the crosses	Abbreviation
1.	Chowghat Orange Dwarf x Arasampatti Tall	To get a dwarf statured tree, earliness in flowering along with high yield for both tender nut and copra production	COD x ALR
2.	Arasampatti Tall x Malayan Green Dwarf	To get earliness in flowering along with high yield, high quality and more quantity of tender nut water, to impart tolerance to biotic and abiotic stresses in the hybrid	ALR x MGD
3.	Malayan Green Dwarf x Arasampatti Tall	To get early yielding dwarf statured trees with high quantity and quality of tender nut, to get high yield for both tender nut and copra production	MGD x ALR
4.	Chowghat Orange Dwarf x West Coast Tall	To produce high yielding early flowering hybrid tolerant to root wilt disease.	COD x WCT
5.	Kenthali Dwarf x Arasampatti Tall	To obtain high quality tender nut water traits of KTD to future hybrid, to produce pest and disease tolerant hybrid	KTD x ALR
6.	West Coast Tall (Check variety 1)	A superior high yielding and early bearing tall variety, comes to flowering in 58 months. The average nut yield is 152 nuts per palm per year with estimated copra yield of 3.6 t/ha per year. Suitable both for rainfed and irrigated conditions	WCT
7.	Kalpatharu (Check variety 2)	This variety is suitable for ball copra production. It yields around 116 nuts per palm per year with copra content of 176 g, under rainfed condition. This is tolerant to drought	TPT

The hybrids were produced by using the emasculation and hand pollination techniques as detailed. Male flowers were collected from the male parental palms before opening of individual male flowers and 2-4 days after the opening of inflorescence by observing the bluish green tinge at the tip which indicates maturity of the male flowers. These matured male flowers were placed in between two sheets of butter paper and slightly crushed using a wooden rolling pin to separate the perianth parts to collect pollen after drying the same at 40^{o}C for 24 h by sieving with mesh size of 0.2 mm. Bagging was attempted to prevent pollination in emasculated inflorescence by natural

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means 3-4 days before the initiation of female phase in an inflorescence. The pollen grains were mixed with a purified talc in 1:9 ratio and applied on receptive inflorescence for the purpose of pollination. On completion of the fertilization process the stigma turns brown and the secretion of nectar stops. After 3-5 days, when all the buttons in an inflorescence attain this stage, the pollination bags were removed and the bunches were labelled. Mature nuts were harvested 11-12 months after pollination in female parental palms and used to raise the hybrid seedings of coconut for evaluation purpose (Niral et al., 2009). The experiment was laid out in randomized block design (RBD) with four replications maintaining six palms per treatment per replication. Ten-month-old vigorous and healthy seedlings of each cross combination, along with seedlings of check varieties, were selected and planted during 2012 with a spacing of 7.5 × 7.5 m under irrigated conditions, duly following the standard package of practices recommended (Tamil Nadu Agricultural University Crop Production Guide, 2012). The hybrids were evaluated for growth and yield parameters along with parents. The growth parameters such as palm height, trunk girth, number of functional leaves on the crown, leaf length, petiole length, number of spikelets per inflorescence and number of female flowers per inflorescence were recorded in all the palms during June 2020 at full bearing stage. The palm height was measured from base of trunk to tip of the second leaf from top (cm); trunk girth measured at 1 m height from the base of the trunk (cm); annual leaf production measured as new leaf production from June to May were counted and expressed in numbers; length of the leaf petiole from point of attachment to the tree to the point of the first leaflet insertion; length of the leaves were measured from base of the petiole to tip of the leaf (cm); numbers of photosynthetically active leaves were counted and expressed in numbers; number of spikelets produced per inflorescence were counted after opening of the spathe; number of female flowers per inflorescence were counted after opening of the spathe. The nut yield per palm was recorded periodically at each harvest and the data from July 2016 to June 2020 were used to derive nut yield per palm per year. Copra content per nut was recorded by collecting a random sample of ten nuts per each entry in each replication during harvest. Copra output per palm was calculated based on the copra content per nut in each treatment. Observations in parents were recorded from the existing grownup palms. The mean values of all the traits were subjected to Analysis of Variance (ANOVA) on the basis of model proposed by Panse and Sukhatme (1969). The above data analyses were performed using WASP (Web Based Agricultural Software Package) data analysis software (2004).

Results and discussion

Growth characters

The growth characteristics of the experimental palms at the age of 9 years are presented in *Table 3*. The growth parameters namely trunk girth, petiole length and leaf length did not vary significantly among the hybrid combinations studied. However, there were notable differences in palm height, number of functional leaves and annual leaf production among the hybrids evaluated. The COD x WCT hybrid recorded the lowest palm height (240.0 cm), followed by COD x ALR (274.6 cm) indicating their dwarf nature compared to other hybrids. The dwarf nature may be attributed due to the use of the dwarf cultivar (COD) as the female parent (Ramanandam et al., 2018). On the other hand, the ALR x MGD cross recorded the maximum palm height (334.9 cm).

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Table 3. *Performance of coconut hybrids for growth parameters*

Hybrids	Palm height (cm)	Trunk girth (cm)	Petiole Length (cm)	Leaf length (cm)	Number of functional leaves	Annual leaf production
COD x ALR	274.6	86.7	143.0	525.3	25.8	11.2
ALR x MGD	334.9	163.6	153.7	542.0	25.0	10.6
MGD x ALR	299.8	93.2	145.3	508.4	25.1	11.2
COD x WCT	240.0	85.9	148.3	531.1	24.8	10.7
KTD x ALR	287.1	87.4	147.4	537.9	26.6	10.7
WCT (c)	223.8	120.3	162.2	529.1	31.9	10.4
Kalpatharu (c)	169.4	159.2	164.3	557.0	27.8	9.5
S. Ed.	29.6	NS	NS	NS	1.4	0.5
C.D. (5%)	62.3	NS	NS	NS	3.0	1.1

Regarding the number of functional leaves on the crown, the hybrid KTD x ALR recorded the highest number of functional leaves (26.6) followed by COD x ALR (25.8). The highest rate of annual leaf production was maximum in the hybrid COD x ALR (11.2 per palm per year), MGD x ALR (11.2 per palm per year) followed by COD x WCT (10.7 per palm per year) and KTD x ALT (10.7 per palm per year). A high rate of leaf production during the early growth phase of the tree is positively correlated with early flowering, nut yield and copra yield and indicating the future yield potential of the hybrid (Liyanage et al., 1988).

Floral and yield parameters

Significant variation was observed among the coconut hybrids in floral and yield parameters, including the number of spikelets per inflorescence, number of female flowers per inflorescence and nut yield per palm per year (*Table 4*). Among the five hybrid combinations, MGD x ALR exhibited the earliest flowering (34 months), followed by COD x ALR, COD x WCT, and KTD x ALR, with the first spathe emerging 37 months after planting. The early flowering in MGD x ALR could be due to the involvement of semi-tall cultivar MGD as the female parent, which flowers within 54 months after planting (Niral et al., 2009). The number of spikelets per inflorescence ranges from 22.8 in the local check variety West Coast Tall to a maximum of 34.9 in KTD x ALR. N'cho et al. (1993) and Pillai et al. (1988) have highlighted the importance of inflorescence and nut characteristics in characterizing and classifying coconut cultivars (*Fig. 2*).

Table 4. *Performance of coconut hybrids for yield and tender nut quality*

Hybrids	Age at first flowering (months)	No. of spikelets/inflorescence	No. of female flowers/inflorescence	Nut yield (number/palm/year	Tender nut water content (ml/tender nut)
COD x ALR	37	31.9	24.2	82.5	283.0
ALR x MGD	38	32.3	20.0	77.3	219.6
MGD x ALR	34	30.7	18.5	67.7	325.0
COD x WCT	37	30.9	18.7	56.8	317.0
KTD x ALR	37	34.9	13.2	67.6	296.5
WCT (c)	49	22.8	12.3	25.6	236.8
Kalpatharu (c)	53	27.3	20.3	22.1	233.8
S. Ed.	0.7	3.2	4.6	3.2	4.5
C.D. (5%)	1.5	6.8	9.6	6.8	9.9

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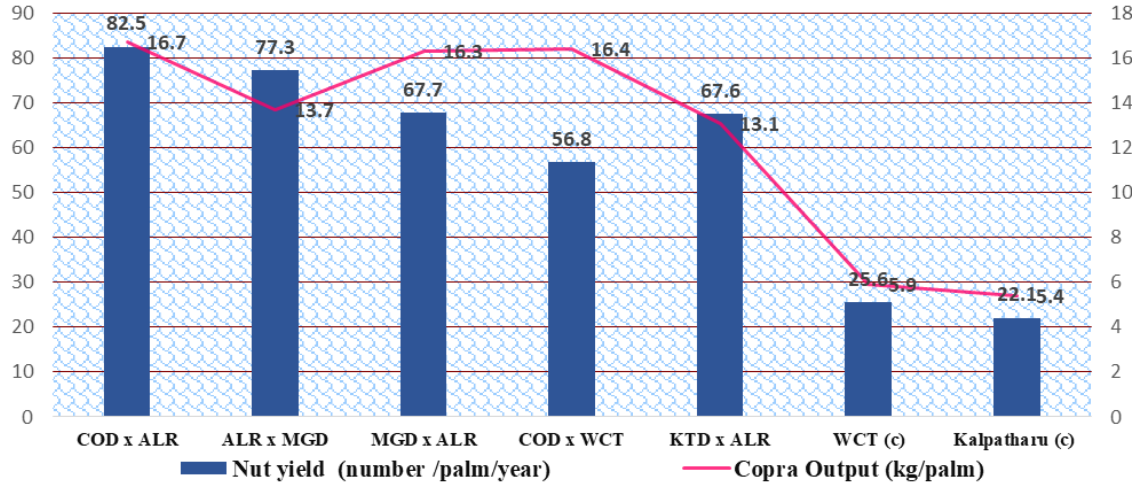

Figure 2. *Performance of coconut hybrids for nut yield and copra content*

The COD x ALR hybrid combination recorded the highest number of female flowers (24.2 per bunch). This increased tendency towards female flower formation can be attributed to the female flower production potential inherited from COD, as it was used as female parent in the hybrid (Thangahemavathy and Balaji, 2008). The present findings align with the reports of Kanimozhi et al. (2018a), indicating that D×T hybrids exhibited a higher number of female flowers compared to their parents.

Significant differences were recorded among the hybrids in terms of annual nut yield. The results revealed that the maximum nut yield (averaged over three years) was recorded in the hybrid COD x ALR (82.5 nuts per palm per year), followed by ALR x MGD (77 nuts per palm per year). The hybrids exhibited higher nut yield compared to the parents and varietal checks, which could be attributed to their heterotic effect. The coconut varietal population in India is enriched with numerous genetic variability due to its pollination mechanism and long-standing cultivation practices (Ramanandam et al., 2017). When dissimilar alleles from diverse genes are brought together, there is a combined allelic expression leading to heterosis (Birchler et al., 2010). In the present study, the heterotic expression COD x ALR hybrid was prominently exhibited. Similar findings were reported by Kumaran et al. (2006), Jayabose et al. (2008), Jerard et al. (2015) and Shinde et al. (2018). The hybrid MGD x ALR exhibited the highest water content in the tender nut (325 ml/tender nut), followed by COD x WCT (317ml/tender nut). These results align with previous findings by Ramanandam et al. (2017) and Kanimozhi et al. (2018b), where D×T hybrids recorded the maximum quantity of water in tender nuts.

Nut traits

Significant differences were observed in nut characteristics and copra yield among the hybrids, parents and check varieties evaluated, except for kernel thickness (*Table 5*). The hybrid COD x WCT exhibited significantly higher nut length (25.6 cm), nut breadth (16.3 cm), whole nut weight (2421 g), de-husked nut weight (1086 g) and copra weight per nut (247.5 g). With respect to copra output per palm per year, the COD x ALR hybrid (16.7 kg per palm per year; 3.0 t/ha) was identified as superior, followed by COD x WCT (16.4 kg per palm per year; 2.8 t/ha). Similar results were reported by Rao

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et al. (2002) and Ramanandam et al. (2017) in D x T coconut hybrids. The higher nut yield in the COD x ALR hybrid may be the reason for its higher copra yield compared to the parents and check varieties. The superior performance of the COD × ALR hybrid could be attributed to the specific combining ability of COD × ALR or the usage of ALR as a pollen parent (Nath et al., 2017).

Table 5. *Performance of coconut hybrids for nut traits*

Hybrids	Fruit length (cm)	Fruit breadth (cm)	Whole nut weight (g)	De-husked nut weight (g)	Kernel thickness (cm)	Copra weight (g)	Copra output (kg/palm)	Copra output (t/ha)
COD x ALR	20.3	14.2	1414.8	734.3	1.5	191.8	16.7	3.0
ALR x MGD	24.7	13.9	1642.5	572.0	1.3	160.0	13.7	2.4
MGD x ALR	21.4	15.0	1656.5	801.5	1.3	210.8	16.3	2.7
COD x WCT	25.6	16.3	2421.0	1086.0	1.4	247.5	16.4	2.8
KTD x ALR	21.2	14.2	1516.8	627.8	1.2	160.5	13.1	2.3
WCT (c)	20.9	13.6	1129.8	534.3	1.3	175.0	5.9	1.1
Kalpatharu (c)	19.3	14.2	941.0	456.3	1.3	147.8	5.4	1.0
S. E.	0.4	0.2	73.2	33.4	NS	18.0	0.2	0.3
C.D. (5%)	0.8	0.5	153.8	70.1	NS	37.7	0.5	0.7

The phonotypical traits of the parental and hybrid palms are narrated in *Table 6*. The palms of this (COD X ALR) hybrid are semi-tall without prominent bole and attain an average height of 274.60 cm at 9 years after planting.

Table 6. *Morphological and fruit traits of COD x ALR with parental palms*

S. No.	Parameters	Female parent	Male parent	COD x ALR
1	Category	Dwarf	Tall	Semi tall
2	Crown shape	Circular	Circular	Circular
3	Presence of bole	Absent	Present	Present
4	Plant height (cm)	408.20	987.60	274.60
5	Girth of trunk (cm)	63.50	96.70	86.70
6	Total number of leaves	24.60	34.50	30.80
7	Length of petiole (cm)	94.40	127.90	143.00
8	Leaf length (cm)	453.60	512.40	525.30
9	Annual leaf production (numbers)	11.40	10.20	11.70
10	Age at first flowering (months)	44.00	66.00	37.00
11	No. of spikelets in the inflorescence	30.60	24.70	31.90
12	Number of female flowers per inflorescence	19.80	17.30	24.20
13	Length of fruit (cm)	19.50	21.30	20.30
14	Breadth of fruit (cm)	12.50	13.10	14.20
15	Weight of fruit (g)	654.70	1256.00	1414.80
16	De-husked nut weight (g)	546.70	454.40	734.30
17	Kernel thickness (cm)	0.80	1.30	1.50
18	Weight of copra per fruit (g)	134.70	131.40	191.80
19	Copra output (kg/palm)	7.80	14.60	16.70
20	Copra output (t/ha)	1.40	2.60	3.00
21	Nut yield (number/palm/year)	67.80	78.90	82.50
22	Tender nut water content (ml/tender nut)	267.90	212.40	283.00

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The hybrid palms recorded elevated values than dwarf parental palm for the traits viz., trunk girth (86.70 cm), total number of leaves (30.80), length of petiole (143.00 cm), leaf length (525.30 cm), annual leaf production (11.70), number of spikelets in the inflorescence (31.90), number of female flowers per inflorescence (24.20), length of fruit (20.30 cm), breadth of fruit (14.20 cm), weight of fruit (1414.80 g), de-husked nut weight (734.30 g), kernel thickness (1.50 cm), weight of copra per fruit (191.80 g), copra output (16.70 kg/palm), copra output (3.00 t/ha), nut yield (82.50 number/palm/year) and tender nut water content (283.00 ml/tender nut). The hybrid palms exhibited desirable values for growth, yield and yield attributed traits besides as earliness in flowering. This could be due to the mixed allelic expression results from the pairing of two distinct alleles of different parents. Additionally, heterosis would arise if the complementation of alleles in many genes were cumulative in phenotype (Birchler et al., 2003). Similar to this, the heterotic expression of hybrids with distant parent COD with ALR in the current study showed clearly defined the heterosis.

Conclusion

Based on the findings of this present study, the COD x ALR hybrid was found to be superior due to its early flowering, higher nut yield and copra output. This hybrid also exhibited favorable growth characters such as semi-tall stature, circular crown, formation of a bole at the trunk base and long leaves with lengthy petioles. The hybrids, ALR x MGD and MGD x ALR, also exhibited superior performance in terms of annual nut production and copra yield per hectare. Given the increasing demand for hybrids in commercial cultivation, this study results would greatly benefit scientists in refining their research and aid growers in selecting the most suitable coconut hybrid for planting ultimately leading to higher economic return.

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