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First report on dwarf x dwarf coconut (*Cocos nucifera* L.) hybrids at cyclonic east coastal region of India

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Abstract

Coconut, an important commercial plantation crop of India, is extensively grown from the state of Gujarat in the West Coast to West Bengal in the East Coast along the coastal lines of Peninsular India and is spreading inland over the non-traditional areas. The increased demand for fresh consumption and tender coconuts led the breeders towards development of dwarf hybrids for the benefit of the farming community. With this objective an experiment was initiated during 2011 to study the feasibility of growing D x D hybrids. The dwarf hybrids exhibited trunk height of *i.e.*3.8 to 5.5m height at 13 years of age. The tender fruit weight ranged between 741.43g (DDCH 3) to 1180.33g (DDCH 4). In DDCH 4, the yield of endosperm (57 liters) was also significantly higher than the check (22.65 liters) which indicate the prolific yield for beverage purpose. The PCA analysis of reproductive parameters revealed that, the total inflorescence per palm, number of spikelets per palm, number of male and female flowers per inflorescence had positive contribution (PC1). With higher yield and better quality parameters, the hybrid DDCH 4 was first D x D hybrid observed to be suitable for the East Coast region of Tamil Nadu.

Keywords: Coconut; dwarf; cyclone; tender nut yield; potassium; sodium; reducing sugars; total sugars

Introduction

Coconut palm is widely regarded as "*Kalpa Vriksha*" or tree of life due to usefulness of all of its parts and is the most extensively grown genus among the palm crops. It belongs to the woody monotypic genus *Cocos* and is a diploid species (2n=2x=32). The coconut is used to produce oils, nutraceuticals, crafts from shells, construction materials and wood in construction business (DebMandal, Mandal 2011). India, Indonesia, Philippines and Sri Lanka are the top countries in coconut production (Vanaja, Kavin 2021). Coconut palms are perennial with long pre-bearing phase and face huge limitations for sustainable production. The major challenges being threats to traditional varieties, lower productivity and stress aggravated by climate change. Till date, there are number of varieties released for commercial cultivation by Tamil Nadu Agricultural University as well as the ICAR-Central Plantation Crops Research Institute *viz*., Tall, Tall x Dwarf, Tall x Tall and Dwarf types. However, there are no Dwarf x Dwarf hybrid recommended for the cyclone prone areas of Tamil Nadu province.

The "Gaja cyclone" hit East Coast of India during November, 2018 and effects were well observed (Kumar, Murugan 2022). At this station, observable differences were visualized in different types and hybrids of coconut *i.e.* Tall, Dwarf, Tall x Tall, Tall x Dwarf and Dwarf

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x Tall except Dwarf x Dwarf crosses. The most severe effect was observed in tall and its hybrids compared to dwarf and its hybrids.

Manthriratna (1972) reported that there are three colour forms in dwarf cultivar *i.e. Cocos nucifera* var. *nana* dwarf green (*pumila*), dwarf yellow (*eburnea*) and dwarf red (*regia*). The dwarf types have short habit, early bearing and a typical formation of bole above the ground level. Gordon and Jackson (2017) reported that Malayan dwarf, seldom exceeds 4–8 m. The yield of the nuts varied between 53 to 100 with mean period for flowering was 36.5 months. Tall coconut had tall trunk and pre-bearing phase *i.e.* 6-8 years while Dwarf had short trunk and pre-bearing age of 3-4years (Novarianto *et al.* 2021).

Aiming the future scenario and demand for commercial coconut production, dwarf hybrids with earliness in flowering, higher tender nut water yield with better quality parameters need to be identified to fulfill the stakeholders need. With this objective, five Dwarf x Dwarf (D x D) hybrids were evaluated to study their adaptability and to identify suitable dwarf hybrids for commercial cultivation.

Materials and Methods

The experiment on Dwarf x Dwarf (D x D) hybrids was initiated at Coconut Research Station, TNAU, Veppankulam, Tamil Nadu state of India during 2009. The experimental block located at 10.4722^{0}N and 79.3783^{0}E at an altitude of 23 MSL and situated on the East coastal region of Tamil Nadu State, India. The average annual rainfall of the location is 1157 mm distributed over 54 days. The weather parameters *viz.*, maximum (T_{max}) and minimum (T_{min}) temperature (^{0}C), rainfall (mm), rainy days (RD) and relative humidity (RH) ware recorded at the Meteorological observatory located at the experimental farm is presented in Figure 1.

The experiment block had sandy loam soil type which has low nitrogen and medium phosphorus and potassium content. The hybrids were produced at ICAR- CPCRI, Kasaragod and provided for MLT at Veppankulam, Ratnagiri and Ambajipeta centres of ICAR-AICRP on palms centres in Tamil Nadu, Maharashtra and Andhra Pradesh states, respectively. The present results pertaininng to the performance at AICRP centre Tamil Nadu is presented in this paper. The details of the crosses are presented in Table 1.

Hybrid production was taken up by artificial hand pollination at ICAR-CPCRI, Kasaragod using the selected mother palms and the hybrid seed nuts of 12 months maturity were transported to the CRS, Veppankulam, under the AICRP on Palms, for establishment of the trial. The seed nuts were sown in the nursery and twelve months old seedlings were transplanted in the main field. The selection of the hybrid seedlings were followed as per the standard procedures (Table 2). Poor seedlings and the odd types with female parent petiole colour were discarded. The experiment was laid out in Randomized Block Design with four replications.

Fig 1. Environmental factors (2013-2022) Tmax (Maximum temperature in ^{0}C), Tmin (Minimum temperature ^{0}C), Rf (Rainfall in mm), RD (Rainy Days in days) and RH (Relative Humidity in %).

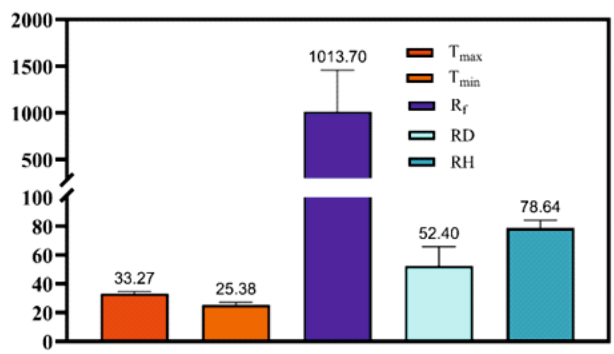


Table 1. Details of the Dwarf x Dwarf hybrids

S.No	Accession No*	Hybrids/check
1	DDCH1	Chowghat Orange Dwarf x Malayan Yellow Dwarf
2	DDCH2	Chowghat Orange Dwarf x Malayan Green Dwarf
3	DDCH3	Malayan Yellow Dwarf x Chowghat Green Dwarf
4	DDCH4	Gangabondam Green Dwarf x Malayan Orange Dwarf
5	DDCH5	Chowghat Green Dwarf x Malayan Green Dwarf
6	DC 1	(Check)Chowghat Orange Dwarf

Table 2. Standard measurement procedures

S. No.	Characteristics	Stage of observation	Type of assessment
1	Palm height (cm)	After trunk formation from base to last leaf of the crown	MS
2	Trunk girth (cm)	Circumference at 1m height	MS
3 4	Annual leaf production (Nos.)	Count total number of leaves produced in one year (12 months)	MS VG
	Functional leaves (Nos.)	Count total number of leaves on the crown	
5	Length of leaflet bearing portion (cm)	To be observed on leaf and the length of leaflet bearing protion to be measured	MS
6	Petiole length (cm)	To be observed on leaf and the petiole length *i.e.* before the leaflet initiation length to be measured	MS
7	Leaflet Length (cm)	To be measured on the longest leaflet on the leaf	MS
8	Leaflet Breadth (cm)	To be measured on the longest leaf let	MS
9	Inflorescence Length (cm)	To be observed on inflorescence opening during the month of Sep-Nov.	MS
10	Number of female (buttons) flowers	To be observed on inflorescence opening during the month of Sep to Nov.	VG
11	Number of male flowers	To be observed on inflorescence opening during the month of Sep to Nov.	VG
12	Total number of inflorescence	To be observed on the palm during July.	VG
13	Fruit Shape (polar view)	To be observed on mature, dry 11-12th month old fruits during March-May	VG
14	Nut position (polar view)	To be observed on immature, 7th month old fruits	VG
15	Fruit Length (cm)	To be observed on mature, dry 11-12th month old fruits	MS
16	Fruit Breadth (cm)	To be observed on mature, dry 11-12th month old fruits	MS
17	Fruit Weight (g)	To be measured on 7th month old fruits	MS
18	Setting percentage (%)	To be observed on inflorescence after harvest	MS
19	Quantity of tender nut water (ml)	To be measured in 7th month old tender nuts during the month of Sep-Nov.	MS

The setting percent and tender nut water yield (TNWY) are calculated as,

$$\text{Setting per cent (\%) per infloresence} = \left(\frac{\text{Total number of nuts harvested}}{\text{Total number of female flowers}}\right) \times 100$$

$$\text{TNWY per palm} = (\text{TNWC per nut x tender nuts harvested per year})$$

$$\text{TNWY per ha} = \text{TNWY per palm per year x Total number of palms per ha*})$$

*Assumption that at a spacing of 7.5 x 7.5m, 175 palms can be accommodated in one ha.

The digital pH meter was calibrated against standard buffer solutions (Kannangara *et al*. 2018). The samples were mixed well to homogenize and the pH values were measured using the calibrated pH meter. To estimate the electrical conductivity (EC), the conductivity meter was calibrated against standard buffer solutions. The samples were mixed well to homogenize and the conductivity was measured using the calibrated conductivity meter. Determinations of minerals was performed utilizing Atomic Absorption Spectrophotometer model iCE 3300.

Statistical analysis

The experiment was established in Randomized Block Design consists of 5 hybrids and check variety as treatments with four replications and the quality parameters in Completely Randomized Block Design. The ANOVA and DNMRT analysis was carried out using R studio version 2024.04.1 and graphical software *viz*., GraphPad Prism ver.10 and PAST4.16c were utilized for graphical representations.

Results and Discussion

Coconut is one of the most significant monocotyledonous species and it is a tropical perennial of Arecaceae species. Ekanayake *et al.* (2010) reported that coconut includes three main varieties *viz.,* tall (*typica*), dwarf (*nana*) and intermediate (*aurantiaca*). The first coconut D x D hybrid was developed at Fiji islands and it was a cross between Niu Leka (Dwarf) and Malayan Red Dwarfs (Marechal 1928). In India, the first hybridization in coconut was initiated during 1932 at Coconut Research Station, Nileswaram (Patel 1938) and the first hybrid Veppankulam Hybrid Coconut 1 (VHC 1) was released during 1982 from Coconut Research Station, Veppankulam. In India, the first systematic evaluation of Dwarf x Dwarf hybrids was established by ICAR-Central Plantation Crops Researtch Institute at CPCRI Research Centre Kidu during 2003, as two hybrid evaluation trials laid out in line x tester design involving eight hybrids with two dwarf parents and Diallel design involving 15 hybrids and 6 dwarf parents (CPCRI 2004). The manifestation of heretrosis in dwarf coconut hybrids was reported from the evaluation of these Dwarf x Dwarf hybrid combinations (Niral *et al* 2022).

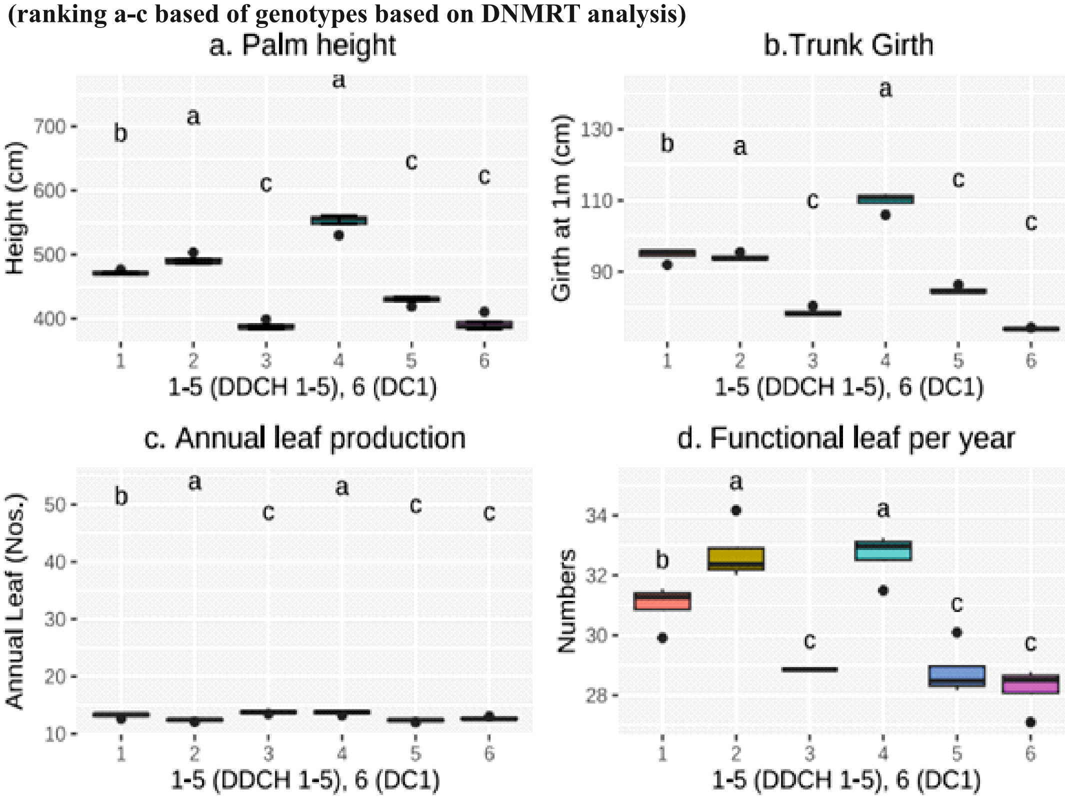
Dwarfs are characterized by slow growth (Swaminathan, Nambiar 1961), early flowering (Jerard *et al*. 2015), large numbers of relatively small fruits, early fruit set and a relatively short life span (Perara *et al.* 2016). Genetically dwarfs have narrow genetic variability compared to tall genotypes due to its autogamous nature (Mahayu *et al.* 2021) with short internodes (Novarianto *et al*. 2021).

Morphological parameters

Palm height

The morphological parameters are presented in Figure 2. At 13 years of age, the trunk height varied significantly among the crosses in this experiment. Dwarf palms were observed in DDCH 3 (388.86cm) and the check DC 1 (392.44cm) was on par. Taller palms were observed in DDCH 4 (550.67cm) and it was significantly different from other crosses.

Figure 2. Variation in mean performance of growth parameters of Dwarf x Dwarf crosses (ranking a-c based of genotypes based on DNMRT analysis)



Haldane (1958) reported that the dwarfism in coconut is governed by a single gene '*DD*' in dwarf and '*dd*' in tall or in combination. In the present study, the cross DDCH 4 exhibited taller plants than its parents and might probably due to the presence of "*Dd*" *i.e.* heterozygous for plant height. It may be due to the tree to tree variation in either one or both the dwarf parents and their imposed hybridity would have led the off springs to vigorous progenies and superior economic traits (Ninan, Satyabalan 1964) and GBGD in India was noted as intermediate group as that of Niu Leka Dwarf in Fiji (Ekanayake *et al.* 2020). Thomas *et al.* (2015) observed that CGD expressed more dwarfness with high degree of homozygosity at molecular level compared to MGD. In the current study, when CGD was used as donor parent, the height of the palm was reduced compared to its reciprocal.

Trunk girth

The trunk girth at 1m height was lower in DDCH 3 (78.57cm) and DDCH 5 (84.80cm) and was on par with DC 1 (74.00cm) . Higher stem girth was observed in DDCH 4 (109.83cm) and it was significantly different from other crosses. The average palm girth was 89.35cm and three crosses were below the average. Manthriratna (1972) reported that in dwarf types, the bole formation was practically absent and the trunks are of uniform girth at the soil surface and about a metre above ground level. Same results were observed in the experiment, however in case of DDCH 4 alone the bole breadth was higher, which is another indication of heterozygosity in the parent population.

Leaf parameters

The development of coconut plants depends on the formation of new leaves which decreases under unfavourable conditions causing premature aging, fall of existing leaves and reduced productivity (Carr 2011). Pronounced morphological differences will highly impact on the economic parameters of the dwarf hybrids. In the current study, the average leaf production was 30.38 and three crosses exceeded the grand mean. Higher number of leaf in a palm may be directly correlated to the economic value of coconut (Femond, Brunin, 1966; Ramadasan, Mathew 1977 and Sudha *et al.* 2019). In the current study, DDCH 2 and DDCH 4 recorded significantly higher number of functional leaves per palm.

The length of the leaflet bearing portion varied from 284.22 cm (DC 1) to 345.67cm (DDCH 4) and the petiole length varied from 99.57cm (DDCH 3) to 131.17cm (DDCH 4). The entire cross combinations had a total leaf length above 400 cm except DC 1 (390.66cm). The longest leaflet length was observed in DDCH 5 (113.00cm) and DDCH 4 was on par (112.33cm) and both of the crosses were significantly different from other cross combinations. The total leaf length in the GBGD (400cm) and MOD (462.8cm), indicated resemblance of DDCH4 to the male parent, however the colour of the petiole resembled that of the female parent. Hence the change in leaf parameters might be due to the synergistic effect of both the parents. Sousa *et al.* (2005) reported that increase in total length of leaf increases the total leaf area in dwarf palms and the leaf area will be same for all the fully opened leaves.

Table 3. Leaf attributes of Dwarf x Dwarf cross combinations

Crosses	Length of leaflet bearing portion (cm)	Petiole length (cm)	Leaflet length (cm)	Leaflet Breadth (cm)
DDCH 1	337.20 ± 9.16ab	118.60 ± 3.53b	108.80± 1.41b	7.00 ± 0.41a
DDCH 2	323.45 ± 1.53c	118.64 ± 1.37b	103.09± 3.12c	6.00 ± 0.05a
DDCH 3	301.57 ± 9.65d	99.57 ± 3.00e	107.00± 1.00b	6.00 ± 0.09a
DDCH 4	345.67 ± 4.94a	131.17 ± 2.22a	112.33± 2.40a	6.67 ± 0.10a
DDCH 5	327.10 ± 9.34bc	112.10 ± 2.11c	113.00± 0.62a	6.00 ± 0.19a
DC1 (check)	284.22 ± 3.86e	106.44 ± 0.45d	101.00± 3.34c	6.11 ± 0.8a

Flower parameters

The coconut palm is monoecious *i.e.* its inflorescence has both staminate (male) and pistillate (female) flowers. In contrast to tall, self pollination was observed in dwarfs as it can shed and receive pollen at the same time. However, the inflorescence traits vary significantly across genotypes. Dwarf types are known for the earliness in flowering compared to the tall. The hybrid DDCH 3 was the earliest to flower (22 months after planting) and same cross expressed earliness in 50% flowering (31 months after planting) in the population (Fig 3). Labouisse *et al.* (2005) reported that MYD exhibited earlier germination coupled with 32 months for 50 % flowering. These results indicate the effect of MYD in DDCH 3 cross. The total length of inflorescence was higher in DDCH 1 (102.00 cm) and it was significantly different from other crosses. All the other cross combinations were between 83.55cm and 90.90cm. The number of male flowers exceeded 4000 flowers in DDCH 1, DDCH 2 and DDCH 4. The number of female flowers per inflorescence ranged between 18.29 in DDCH 3 and 30.20 in DDCH 1. The total number of inflorescence per year ranged between 10.60 (DDCH 5) and 13.29 (DDCH 3) and the grand mean was 11.83. Thomas *et al.* (2015) reported that the number of female flowers in dwarf cultivars varied from 14 to 29 per inflorescence. The cross DDCH 1 recorded the highest number of female flower while DDCH 3 was lower which indicates the specific combining ability of DDCH 1 and importance of IND 058 as donor parent. MYD was donor parent in the commercial coconut hybrids *viz.*, VHC 2, Kerasree, Kalpa Samrudhi and Kalpa Srestha.

Fig. 3. Earliness in DxD coconut crosses and * indicating the on-par genotypes

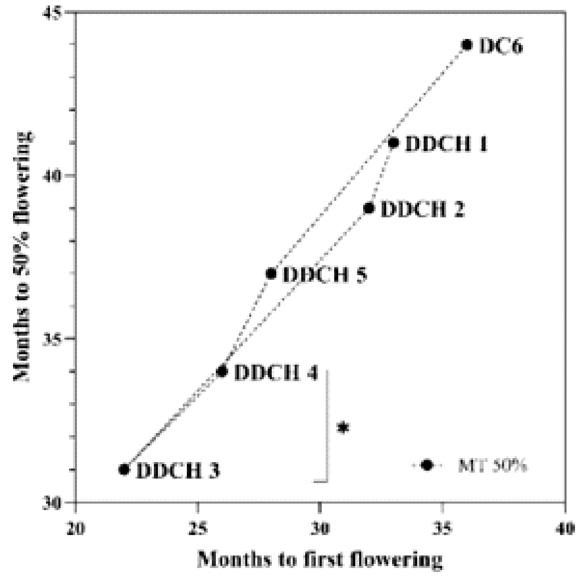


Fig 4. PCA of inflorescence traits MIstF-Months to first flowering: M50% F- Months to 50% flowering: IL- Infloresence lenght; L SBP- Lenght of spiklet bearing protion; STL- Stalk lenght; SPI L- Spiklet lenght; SPI N- No of Spikes: TMF/I- Total No of Male flowers per infloresence: TFF/I- Total по of Female flowers per infloresence; TI/I- Total infloresence per palm; TFF/P- Total female flowers per palm: Y/P/Y- Yield per palm per year

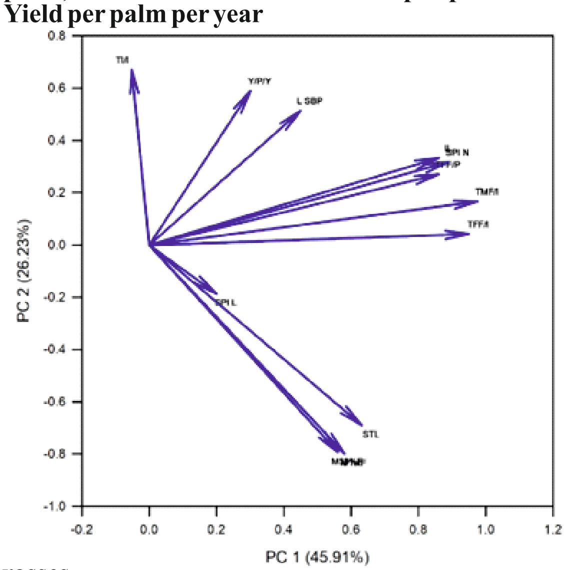


Table 4. Inflorescence parameters of Dwarf x Dwarf crosses

Hybrids	Length of inflorescence (cm)	Length of spikelet bearing portion (cm)	Length of stalk (cm)	Length of spikelet (cm)
DDCH 1	102.00 ± 1.52^{a}	42.80 ± 0.81^{a}	32.80 ± 0.60^{a}	38.60 ± 1.22^{c}
DDCH 2	83.55 ± 1.59^{c}	30.55 ± 0.87^{d}	33.73 ± 0.94^{a}	37.00 ± 0.27^{d}
DDCH 3	83.00 ± 0.39^{c}	35.38 ± 0.36^{c}	28.88 ± 0.67^{c}	36.63 ± 0.29^{d}
DDCH 4	89.00 ± 1.63^{b}	30.50 ± 0.70^{d}	31.17 ± 0.35^{b}	42.83 ± 0.63^{a}
DDCH 5	90.90 ± 1.05^{b}	39.60 ± 0.16^{b}	31.20 ± 0.27^{b}	38.70 ± 0.68^{c}
DC 1 (check)	84.33 ± 1.66^{c}	29.40 ± 0.12^{e}	32.80 ± 0.68^{a}	40.80 ± 0.60^{b}

±- SD; P(<0.05)

A direct correlator to yield is the number of female flowers per inflorescence and number of spathe per palm *i.e.* total number of female flowers (buttons) per palm (Feng *et al.* 2015). To confirm, Principal Component Analysis was carried out to study the interrelationships of reproductive parameters in coconut. The first principal component is the largest contributor to the total variation in the population followed by subsequent components (Lezzoni, Pritts 1991). In the present study (Fig 4.) it was observed that the PC 1 exhibited 45.91% and PC2 (26.3%) variability. It was observed that, the yield has close and positive relation with the length of spikelet bearing portion followed by total number of inflorescence per palm. Positive contribution was observed from male and female flowers per inflorescence, number of spikes and inflorescence length.

Fruit shape, size and colour

The fruit shape was oval in all cross combinations. The fruit length significantly varied between DDCH 2 (20.45cm) and DDCH 4 (18.33cm) was on par. The lower fruit length was observed in 16.76 cm (DDCH 3). Significant variations were observed for fruit breadth among the cross combinations. The breadth ranged between 13.14 cm (DDCH 3) and 14.91 cm (DDCH 2) and the grand mean was 14.24cm. The nut position was at the center in DDCH 1, DDCH 2, DDCH 3 and DC 1, while it was at the bottom in DDCH 4 and DDCH 5. Bourdeix (1988) reported that the color of coconut fruit results from the expression of two independent genes as "*R, r, G, g*". The "*rr gg*" genotype indicate yellow phenotype (DDCH 1); genotypes whose allele "*Rr gg*" signify red or orange phenotype (DC 1); genotypes with allele "*rr Gg*" show green phenotype (DDCH 2, DDCH3 and DDCH 4) and other combinations produce brown phenotype *i.e. Rr Gg*. In dwarf, fruit shape, size and colour are genetically determined and not by environmental effects (Niral and Jerard, 2018)

Fruit weight

In the current experiment, the fruit weight ranged between 741.43g (DDCH 3) to 1180.33g (DDCH 4). Two genotypes exceeded the grand mean of 895.08g. The cross DDCH 4 was significantly different from other crosses. The higher fruit weight was attributed by the additive effects of both GBGD and MOD, where in both parents recorded more than 1000g tender fruit nut weight (Natrajan et al. 2011). In an experiment, Sumitha *et al.* (2020) observed significant differences in fruit weight, when GBGD was used as female parent.

Tender nut water content

The economic parameter of this D x D cross, is the tender nut water content (TNWC) per nut and yield. Significantly higher tender coconut water content was observed in DDCH 4 (603.83ml) per nut and the mean of all crosses for TNWC was 439.10ml. Only two crosses exceeded the grand mean and three crosses above the check. As a result, the tender nut water content per palm per year was higher in DDCH 4 *i.e.* 58.57 liters. It was significantly different from other crosses. In this parameter, all the cross combinations except DDCH 3 exceeded the check variety DC 1 and recorded more than 5000 liters per hectare. Sahoo *et al.* (2021) reported that tender nut water content was significantly higher in GBGD × PHOT (362.0 ml nut^{-1}), ECT × GBGD (354.0 ml nut^{-1}) and LCT × GBGD (352.4 ml nut^{-1}) which indicate that GBGD has good combining ability with the tall as well as with dwarf as observed in the current study.

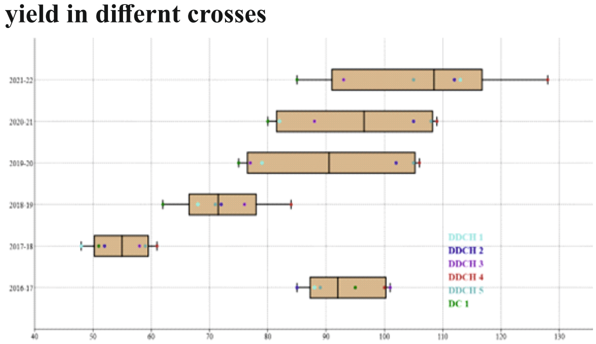
Setting percent

The yield of tender nut highly depends upon the number of female flowers and setting percentage of the crosses. Significant variations were observed in all the crosses. The cross DDCH 5 registered higher setting percentage *i.e.* 33.78% and DDCH 2 (32.38%) was on par. Thomas *et al.* (2015) observed higher heterozygosity at molecular level in Kalparaksha and reported that 40% of out crossing was possible. Four crosses exceeded the grand mean of 28.88%. All the DxD crosses yielded significantly higher than the check. Simillar differences in setting percentage of TxD and DxT was observed by several workers (Nath *et al.* 2017; Sumitha *et al.* 2020)

Tender nut yield

The tender nut yield was recorded from 2016 to 2023 and during 2018, there was incidence of GAJA cyclone. The tender nut yield varied significantly across the experiment. DDCH 4 recorded significantly higher nuts *i.e.* 128 with low standard deviation which indicates its suitability to the East coast region of Tamil Nadu. The pooled mean indicates that the cross DDCH 4 recorded higher yield *i.e.*78 nuts per palms and it was 41% higher than the check. In this experiment, it was observed that higher the palm height, higher the tender nut water content per hectare (Fig 5). The cross DDCH 4 recorded higher plant height coupled with higher yield of tender nut water per hectare at an age of 13 years. Apart from higher yield, the other cross combinations also followed the same pattern *viz*., DDCH 3 recorded lower, followed by the check which are almost similar in palm height and yield. The same cross recorded higher number of nuts per year (97 nuts) and it was significantly higher than the check (DC 1) *i.e.*54.89 nuts. Since both the nut yield and liquid endosperm content per nut was higher in DDCH 4, the yield of liquid endosperm (57 liters) was also significantly higher than the check (22.65 liters) which indicate the prolific yield for beverage purpose and performance of hybridity in dwarf coconuts. In Sri Lanka, Perera *et al*. (2014) reported that considering both nut number and the amount of liquid endosperm, King Coconut was considered as the best beverage coconut.

Figure 5. Environmental influence on tendernut yield in differnt crosses



Tender nut water quality parameters

The quality parameter *viz*., total soluble solids, pH, electrical conductivity, total sugar, reducing sugar, sodium, potassium, phosphorus, calcium and magnesium content were estimated and presented in Table 5. All the parameters exhibited significant variations among the crosses evaluated in the experiment.

Total soluble solids

All the crosses exhibited similar Total Soluble Solids content. TSS content was significantly higher in DDCH 4 (5.57^{0}Brix) and lower in the check (5.09^{0}Brix). Two crosses exceeded the grand mean of 5.32^0 Brix. Similar results were recorded by Sumitha et al. (2020) and in that experiment GBGD when used as female parent, the TSS was higher compared to other parents.

pH and Electrical conductivity

The pH of the tender nut water was significantly lower in the check *i.e.* 4.60 (DC 1) and sufficiently higher in DDCH 1 *i.e.* 5.44 and all the crosses had pH above 5. The electrical conductivity was found to be lower in DDCH 5

Table 5. Flowering characters of Dwarf x Dwarf crosses

Crosses	No. of male flowers inflor.$^{-1}$	No. of female flowers inflor.$^{-1}$	Total number of Inflorescence palm^{-1}	Total number of buttons per palm year^{-1}
DDCH 1	4757.20 ± 29.31^{a}	30.20 ± 3.86^{a}	12.40 ± 0.50^{a}	374.48 ± 48.47^{a}
DDCH 2	4095.64 ± 100.34^{b}	22.55 ± 3.30^{bc}	11.27 ± 0.10^{b}	254.14 ± 30.95^{c}
DDCH 3	3765.86 ± 66.70^{d}	18.29 ± 3.30^{c}	13.29 ± 0.10^{a}	243.07 ± 45.64^{c}
DDCH 4	4078.67 ± 69.40^{b}	25.83 ± 3.26^{ab}	12.00 ± 0.58^{a}	309.96 ± 31.93^{ab}
DDCH 5	3899.30 ± 82.54^{c}	20.00 ± 3.30^{c}	10.60 ± 0.81^{b}	212.00 ± 44.13^{c}
DC1 (check)	3926.22 ± 61.72^{c}	23.11 ± 2.50^{bc}	11.44 ± 0.50^{b}	264.38 ± 24.18^{bc}

± SD; P(<0.05)

(6.87) and DDCH 2 (6.96) was on par. The electrical conductivity of natural coconut water was 5.9±0.3 mS/cm reported by Franco et al. (2015). The minimum spanning tree with 95% ellipses indicate the phylogenetic relationship among the crosses for pH and EC. It indicates that DDCH 4 and DC1 were entirely different from other treatments.

RSTS ratio

The Reducing Sugar, Total Sugar ratio was higher in DDCH 4 and DDCH 1 was on par and both the crosses exceeded 80% was an indication of superior cross combination. Both these combinations were phylogenetically expressing similar expressions for TSS and RSTS ratio. Lopes and Larkins (1993) reported that the edible part of the coconut fruit is the helobial endosperm tissue and the development of coconut endosperm belongs to the nuclear mode. Patrick and Offler (2001) reported that the nutrients from coconut water are obtained from the seed apoplasm (surrounding cell wall) and are transported symplasmically into the endosperm. Components of the liquid endosperm are fatty acids, amino acids, organic acids, enzymes, phenolic compounds, vitamins and minerals. The development of endosperm

Table 6. Fruit components of Dwarf x Dwarf crosses

Crosses	Shape	Length (cm)	Fruit Breadth (cm)	Position	Weight	Setting percent (%)
DDCH 1	O	19.40 ± 0.63[ab]	14.80 ± 0.14[a]	C	854.00 ± 4.57[d]	31.06 ± 3.93[b]
DDCH 2	O	20.45 ± 0.35[a]	14.91 ± 0.22[a]	C	926.27 ± 11.75[b]	43.57 ± 4.75[a]
DDCH 3	O	16.76 ± 1.63[b]	13.14 ± 1.68[a]	C	741.43 ± 3.11[f]	43.03 ± 7.74[a]
DDCH 4	O	18.33 ± 2.46[ab]	14.83 ± 1.79[a]	B	1180.33 ± 36.25[a]	39.90 ± 4.01[ab]
DDCH 5	O	19.00 ± 1.81[ab]	14.30 ± 0.40[a]	B	884.00 ± 19.92[c]	48.62 ± 8.58[c]
DC 1 (check)	O	18.44 ± 2.58[ab]	13.44 ± 0.45[a]	C	784.44 ± 21.39[e]	31.89 ± 3.70[b]

O- Oval; C -centre; B- Bottom; ±- SD; P(<0.05)

Table 7. Economic parameters of Dwarf x Dwarf crosses

Crosses	TNWC (ml^{-1} nut^{-1})	TNWY Yield (L^{-1} ha-1$year^{-1}$)	Tender Nut Yield ($nuts^{-1}$ $year^{-1}$)
DDCH 1	422.20 ± 9.39[c]	6162.01 ± 0.50[c]	114.25 ± 2.50[b]
DDCH 2	384.18 ± 10.78[d]	5568.11 ± 0.99[d]	110.00 ± 2.16[bc]
DDCH 3	327.14 ± 4.57[e]	3606.72 ± 0.61[f]	102.00 ± 6.21[d]
DDCH 4	603.83 ± 2.87[a]	10250.01 ± 0.88[a]	128.00 ± 3.65[a]
DDCH 5	484.60 ± 3.10[b]	6385.82 ± 0.27[b]	105.50 ± 3.10[cd]
DC 1 (check)	412.67 ± 2.38[c]	3964.00 ± 0.31[e]	83.85 ± 2.75[e]

TNWC- Tender nut water content; TNWY- Tender Nut Water Yield; ±- SD; P(<0.05)

Figure. 6. Relationship between trunk height and tender nut yield

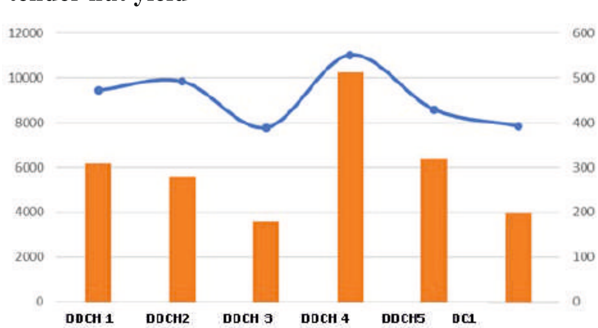


Figure 7. Phylogenic relationship between pH and EC Min.spanning tree and 95% ellipes

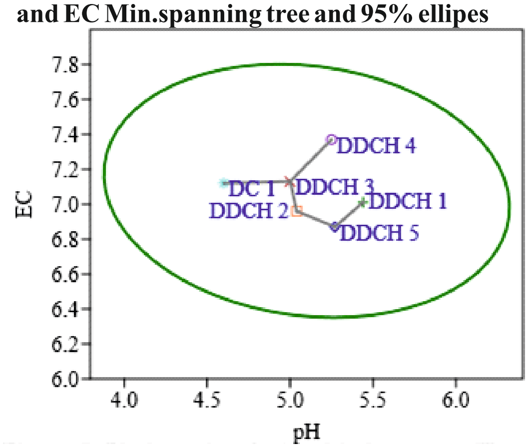
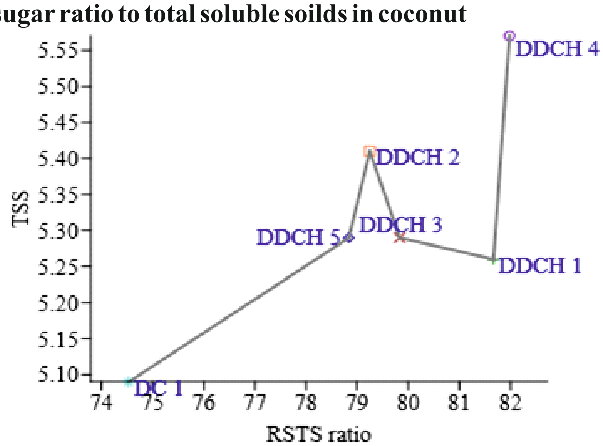


Table 8. Mineral composition of Dwarf x Dwarf crosses

DxD crosses	Sodium content (ppm)	Potassium content (ppm)	Total Phosphrous (ppm)	Total Calcium (ppm)	Total Magnesium)
DDCH 1	21.50 ± 0.55[cd]	2050 ± 46.02[d]	17.30 ± 0.15[b]	81.72 ± 2.16[c]	12.45± 0.17[b]
DDCH 2	22.04 ± 0.12[bc]	2150 ± 70.21[c]	16.17 ± 0.51[c]	83.80 ± 2.28[bc]	11.81± 0.27[c]
DDCH 3	23.12 ± 0.39[a]	2271 ± 21.63[ab]	16.06 ± 0.32[c]	83.65 ± 2.73[bc]	11.89± 0.34[c]
DDCH 4	22.15 ± 0.69[bc]	2202 ± 71.91[bc]	17.60 ± 0.06[ab]	86.67 ± 0.41[a]	12.76± 0.38[ab]
DDCH 5	21.02 ± 0.57[d]	2281 ± 3.10[a]	17.76 ± 0.15[a]	84.48 ± 0.57[ab]	11.98± 0.16[c]
DC 1 (check)	22.56 ± 0.71[ab]	2140 ± 24.75[c]	17.95 ± 0.40[a]	84.42 ± 1.32[ab]	12.88± 0.04[a]

±- SD; P(<0.05)

Figure 8. Relationship between reducing sugar total sugar ratio to total soluble soilds in coconut



and its cytoplasmic origin was well documented by Janic and Paull (2008). Altogether, the molecules confer great nutritional and functional value to coconut water (Rajesh *et al*. 2015) and has recently been promoted as an important source of molecules with nutraceutical potential (Patel *et al*. 2018). A significant variation ($P<0.05$) was observed between the hybrids of coconut water samples.

Mineral content

The sodium content in the tender nut water varied significantly among all cross combinations. Lower sodium content was observed in DDCH 5 (21.02ppm) and the crosses DDCH 1 (21.50ppm), DDCH 2 (22.04ppm) was on par. The mean was 22.06ppm and three cross combinations exceeded the grand mean. The potassium content (ppm) was significantly higher in DDCH 5 (2281ppm) and DDCH 3 (2271ppm) was on par with the cross. All the crosses exceeded the check except DDCH 1 *i.e.* 2050ppm and the grand mean was 2182ppm. The total phosphrous content was higher in the check and three crosses exceeded 17ppm. The total calcium content was higher in DDCH 4 (86.67ppm) and it was significantly different from other crosses. The cross DDCH 1 (81.72ppm) recorded lower calcium content and it was significantly different from other crosses and check. The magnesium content was significantly higher in the check DC 1 (12.88ppm) and DDCH 4 (12.76ppm) was on par. Two crosses and the check exceeded the grand mean of 12.30ppm. The calcium phosphorous ratio of all the hybrids was around 4 to 5 in all the hybrids. Appiah *et al.* (2011) suggested that the Ca:P over 1 tend to make the body acidic and on the converse it will deplete calcium and increase inflammations. Hence the hybrids under the study were nutritionally superior and suitable for consumption. Also, higher Potassium and lower Sodium content was observed in almost all the crosses and the check. The importance of this trait in relation to the health benefits was expressed by Farapti (2016).

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