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Wood Basic Density, Stem Quality, and Disease Resistance of *Corymbia* and *Eucalyptus* Species at North Ruvu Forest Plantation, Kibaha District, Tanzania

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Abstract

Forest plantations in Tanzania play a critical role in supporting sustainable wood supply hence reducing pressure on natural forests. However, expansion of forest plantations in the coastal lowland areas remains constrained by the limited availability of appropriate tree species that combine varieties of traits such as acceptable wood quality, stem form, and resistance to biotic stresses in order to cope with the challenging site conditions. This study evaluated wood basic density (WBD), stem quality, and disease resistance of eight-year-old *Corymbia* and *Eucalyptus* pure species/provenances grown at North Ruvu Forest Plantation, Kibaha District, Tanzania. The trials were established using a randomized complete block design (RCBD), with five replications for *Corymbia* and six for *Eucalyptus*. WBD was determined from increment core samples, while stem quality and disease resistance were assessed in the field using standardized visual scoring systems. The results (presented as mean ± standard error (SE)) shows that (*Corymbia* species/provenances differed significantly in WBD, ranging from 385 ± 18 kg m^{-3} (*C. henryi*, CSIRO) to 475 ± 27 kg m^{-3} (*C. citriodora*, TTSA). In contrast, *Eucalyptus* species showed lower and more uniform WBD values (mean = 394 ± 0.9 kg m^{-3}), with no significant differences detected among entries. *C. variegata* (CSIRO) and *C. citriodora* (TTSA) showed the highest stem quality, with 100% and 92% high-quality stems, respectively. Disease resistance was strongest in *C. citriodora* (TTSA and ZFC) and *E. camaldulensis* (TTSA), where no visible disease symptoms were observed. Overall performance ranking identified *C. citriodora* (TTSA), *C. variegata* (CSIRO), and *E. camaldulensis* (TTSA) as the most promising species/provenances for coastal lowland conditions. These findings demonstrate the strong potential of selected *Corymbia* species as viable alternatives or complements to *Eucalyptus* in Tanzanian plantation forestry and provide empirical guidance for site–species matching and diversification strategies in similar environments.

Keywords

Commercial Forestry, Coastal Environment, Forest Plantation, Increment Cores, Site-species Matching, Species-provenance Selection

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1. Introduction

Global demand for sustainably produced wood products continues to increase, intensifying pressure on natural forests and driving the expansion of plantation forestry worldwide [1]. In sub-Saharan Africa, plantation forests are increasingly recognized as essential components of national strategies aimed at meeting industrial wood demand, enhancing rural livelihoods, and mitigating deforestation and forest degradation [2]. In Tanzania, plantation forestry has played a particularly important role in supplementing wood supply for timber, poles, fuelwood, and pulp, thereby reducing harvesting pressure on indigenous forests [3].

Species of the genus *Eucalyptus* (family Myrtaceae), native primarily to Australia and parts of Southeast Asia, have dominated plantation forestry in Tanzania for several decades due to their rapid growth, broad ecological adaptability, and versatile end-use potential [4]. Despite these advantages, increasing reliance on a narrow range of *Eucalyptus* species and provenances has raised concerns regarding long-term sustainability, particularly under changing climatic conditions and rising biotic stress [5]. Emerging threats from fungal pathogens and insect pests, such as *Chrysoporthe austroafricana*, further highlight the vulnerability of genetically uniform plantations and the need for greater species and genetic diversification [6].

Corymbia, separated from *Eucalyptus* in the 1990s, is gaining attention as a potential alternative for plantations [7]. Several *Corymbia* species are reported to possess high wood density, good mechanical properties, and improved tolerance to pests, diseases, and water stress [8, 43]. However, despite promising international evidence, *Corymbia* remains under-utilized in Tanzanian plantation forestry, and empirical evaluations under local conditions are scarce, particularly at mid-rotation ages when wood properties and stem form become operationally relevant [9].

Wood basic density, stem quality, and disease resistance are key traits determining the technical, economic, and ecological value of plantation species [10]. Wood basic density is closely linked to timber strength, pulp yield, energy content, and carbon storage, while stem quality, expressed through straightness, absence of forking, and overall form, directly influences log recovery and processing efficiency [11]. Disease resistance has become increasingly important as plantations expand into marginal environments and face heightened pathogen pressure associated with climate variability and site stress [12, 37]. Studies elsewhere suggest that *Corymbia* species may exhibit higher wood density and mechanical strength than *Eucalyptus*. However, they may vary in stem form. In contrast, *Eucalyptus* is often valued for its uniformity and industrial suitability but may be more vulnerable to disease and environmental stressors [13, 39]. These differences indicate that the two genera may respond differently in terms of stem quality and wood performance under similar site conditions.

Although numerous studies in Tanzania have evaluated survival and early growth performance of *Eucalyptus* species, comparatively little information is available on mid-rotation wood properties, stem quality, and health status, especially in coastal lowland environments characterized by sandy or weakly developed soils, moderate rainfall, high humidity, and potentially elevated disease pressure [14]. North Ruvu Forest Plantation in Kibaha District represents a typical coastal lowland site where such challenges are evident, yet comparative performance data for *Corymbia* and *Eucalyptus* under these conditions remain limited [15].

This study addresses this knowledge gap by providing a site-specific, mid-rotation comparison of selected *Corymbia* and *Eucalyptus* pure species/provenances at eight years of age. *Corymbia* species are hypothesized to perform better under coastal lowland conditions, showing higher wood density, variable stem form, and stronger disease resistance under humid lowland conditions, owing to reported tolerance to fungal pathogens and site-related stress. Accordingly, the objective of this study was to evaluate and compare wood basic density, stem quality, and disease resistance among selected *Corymbia* and *Eucalyptus* species/provenances at North Ruvu Forest Plantation, Tanzania. The findings are intended to support evidence-based species selection, promote genetic diversification, and inform sustainable plantation development strategies in coastal lowland environments of Tanzania and similar regions.

2. Materials and Methods

2.1. Study Area Description

The study was conducted at North Ruvu Forest Plantation, located in the Kongowe area of Kibaha District, Pwani Region, Tanzania (Figure 1). The plantation lies at an elevation of approximately 80 m above sea level and extends between latitudes 6°32′–6°43′ S and longitudes 38°48′–39°02′ E. The climate is characterized by a bimodal rainfall pattern, with a mean annual precipitation of approximately 900 mm. The main rainy season occurs from March to May, while a shorter rainy period is experienced from November to December [16]. Mean annual temperatures range from 18°C to 33°C, with the highest temperatures typically recorded in January and February.

Soils are predominantly well-drained, ranging from sandy to sandy loam and gravelly textures. The soils are slightly acidic, with pH values ranging from 6.1 to 6.7, and are characterized by very low levels of total nitrogen (N) and extractable phosphorus (P) [17]. The natural vegetation comprises semi-deciduous woodland ranging from open to partially closed stands, interspersed with evergreen thickets and patches of riverine forest [18]. Dominant tree species include *Afzelia quanzensis*, *Pteleopsis myrtifolia*, *Strychnos molle*, several *Combretum* and *Albizia* species, *Brachystegia spiciformis*, *Dalbergia melanoxylon*, *Julbernardia globiflora*, and *Vitex doniana*. This diversity reflects the ecological complexity typical of coastal lowland forests in eastern Tanzania.

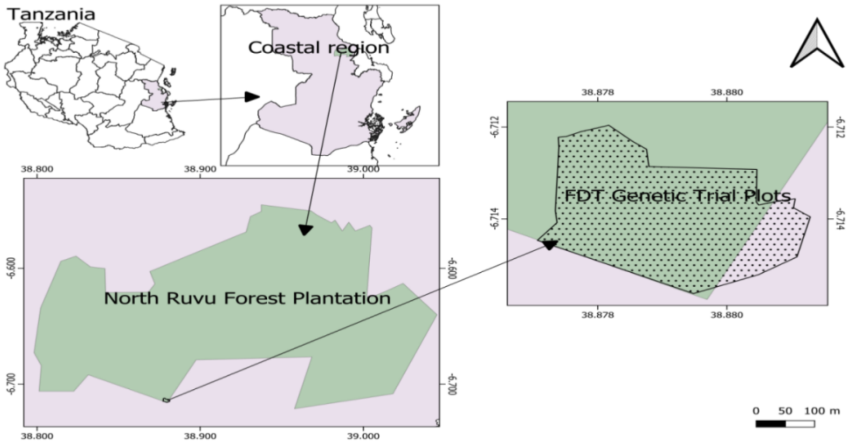

Figure 1. *Map of Tanzania showing the location of the study area at North Ruvu Forest Plantation, Pwani region.*

2.2. Experimental Design

Separate field trials for *Eucalyptus* and *Corymbia* species/provenances were established in 2017 at North Ruvu Forest Plantation by the Forestry Development Trust (FDT). The trials were designed to evaluate wood quality, disease resistance, and stem quality using a randomized complete block design (RCBD), applied independently for each genus (Tables 1 and 2). The *Eucalyptus* trial comprised 26 entries arranged across six blocks, while the *Corymbia* trial consisted of 16 entries distributed across five blocks. Each experimental plot contained 16 trees arranged in a 4 × 4 configuration with a spacing of 3 m × 3 m. Entries were randomized within blocks at establishment to account for site heterogeneity.

Table 1. *List of Corymbia species showing sources, provenance country, soil characteristics, elevation, latitude, and longitude planted at North Ruvu Forest Plantation, Pwani region in Tanzania (Experiment number FDT/RUV/CS/10).*

S/N	Name of species/provenances	Source	Provenance Country	Latitude	Longitude	Elevation (m)	Rainfall (mm)	Temperature (°C)	Soils
1	*C.citriodora*	CSIRO2	Australia	15°S – 30°S	142°E – 153 °E	0 - 500	700 - 1500	15C – 35	Well–drained, sandy loam
2	*C.citriodora*	CSIRO	Australia	18°S - 26°S	140 °E – 152 °E	100 - 800	800 - 1600	15C – 35	Well-drained loams, sandy
3	*C.citriodora*	TTSA	Tanzania	12°S – 13°S	39°E – 40°E	0 - 500	800 - 1200	20 - 30	Sandy loam, clay loam
4	*C.citriodora*	ZFC	Australia	25°S – 30°S	150°E – 155°E	0 - 600	750 - 1200	15C – 30	Gravelly soil
5	*C.henry*	CSIRO	Australia	25°S – 29°S	151°E – 153°E	0 - 1000	600 - 1200	15C – 30	Well-drained, sandy, loamy
6	*C.henry*	TEZA	South Africa	12.5°S – 13.5°S	38.5°E – 39°E	800 - 1200	800 – 1500	15C – 30	Well-drained, sandy, loamy
7	*C.henry*	ZDL	South Africa	17°S – 24°S	145°E – 152°E	200 - 800	800 - 1200	15C – 25	Deep loamy, sandy soil
8	*C.maculata*	CSIRO	Australia	29°S – 37°S	150°E – 152°E	0 - 600	700 - 1200	15C – 25	Sandy loam, clay loamy
9	*C.maculata*	RSA	South Africa	33°S – 35°S	18°E – 25°E	0 - 1000	600 - 1200	12C – 25	Sandy, loam

S/N	Name of species/provenances	Source	Provenance Country	Latitude	Longitude	Elevation (m)	Rainfall (mm)	Temperature (°C)	Soils
10	*C.maculata*	TTSA	Tanzania	6.8°S – 6.9°S	39.22°E – 39.25°E	300 - 350	800 - 1200	25C – 31	Sandy loamy. Well drained
11	*C.maculata*	ZFC	Australia	28°S – 36°S	150°E - 153°E	0 - 300	750 - 1200	15C – 25	Sandy loam, clay loamy
12	*C.torelliana*	RSA	South Africa	22°S – 34°S	16°E – 32°E	0 - 1000	800 - 1800	18C - 28	Sandy loam, clay loamy
13	*C.torelliana*	SF	Australia	15°S – 35°S	138°E – 153°E	0 - 800	800 - 1600	18C – 28	Loamy, sandy soil
14	*C.variegata*	CSIRO	Australia	25°S – 30°S	150°E – 153°E	100 - 700	700 - 1300	15C – 30	Well-drained, sandy loamy
15	*THH1*	RSA	South Africa	28°S – 29°S	31°E – 32°E	100 - 800	600 - 1000	20C – 30	Alluvial, sandy loam, clay
16	*THH2*	RSA	South Africa	28°S – 29°S	31°E – 32°E	100 - 800	600 - 1000	20C – 30	Alluvial, sandy loam, clay

Note: CSIRO2 = Commonwealth Science and Industrial Research Organisation; CSIR = Council for Scientific and Industrial Research; TTSA = Tanzania Tree Seed Agency; RSA = Republic of South Africa; ZFC = Zimbabwe Forestry Commission; SF = State Forests; ZDL =A reginal code used in Forestry trial - Zululand; TEZA = Trial site at TEZA, Kwazulu-Natal, (THH1 & THH2) = *C. torelliana* x *C. henryi*

Table 2. *List of Eucalyptus species showing sources, provenance country, soil characteristics, elevation, latitude, and longitude planted at North Ruvu Forest Plantation, Pwani region in Tanzania (Experiment number: FDT/RUV/EPS/14).*

S/N	Name of species/provenances	Source	Provenance Country	Latitude	Longitude	Elevation (m)	Rainfall (mm)	Temperature (°C)	Soils
1	*E. alba*	CSIRO	Australia	8.0°S - 12.0°S	125.0°E - 130.0°E	0 - 400	1000 - 2000	20 - 30	Sandy loam, well-drained
2	*E. argophloia*	RSA	South Africa	25.0°S - 27.0°S	151.0°E - 153.0°E	200 - 600	600 - 1000	15 - 25	Clayey loam, well-drained
3	*E. longirostrata*	ICFR	South Africa	30.0°S - 31.0°S	26.0°E - 27.5°E	500 - 1200	600 - 1200	$15\text{-}25^0$	Loamy, clayey soils
4	*E. biturbinata*	CSIRO	Australia	30.0°S - 32.0°S	150.0°E - 152.0°E	200 - 800	600 - 1000	15 - 25	Clayey soils
5	*E. camaldulensis*	TTSA	Tanzania	12.0°S - 24.0°S	120.0°E - 135.0°E	0 - 500	250 - 1200	15 - 30	Alluvial soils, loamy
6	*E. cloeziana*	KLF	Australia	20.0°S - 28.0°S	146.0°E - 150.0°E	200 - 900	700 - 1400	15 - 25	Sandy loam
7	*E. coolabah*	CSIRO	Australia	20.0°S - 30.0°S	130.0°E - 145.0°E	0 - 200	250 - 750	15 - 35	Clay, sandy soils
8	*E. grandis*	Mondi-7	South Africa	15.0°S - 28.0°S	30.0°E - 40.0°E	0 - 1500	1200 - 2500	15 - 27	Deep, fertile soils
9	*E. pellita*	SAPPI	Australia	10.0°S - 14.0°S	145.0°E - 150.0°E	0 - 400	1200 - 2000	20 - 30	Loamy, well-drained soils
10	*E. pilularis*	CSIRO	Australia	25.0°S - 30.0°S	151.0°E - 154.0°E	0 - 600	1000 - 1600	15 - 25	Sandy, loamy soils
11	*E. urophylla*	CSIR	Indonesia	30.0°S - 33.0°S	150.0°E - 153.0°E	200 - 800	600 - 1200	22	Clayey soils

S/N	Name of species/provenances	Source	Provenance Country	Latitude	Longitude	Elevation (m)	Rainfall (mm)	Temperature (°C)	Soils
12	*E. saligna*	Mondi-7	South Africa	25.0°S - 32.0°S	145.0°E - 150.0°E	0 - 1000	1200 - 2000	15 - 27	Loamy, well-drained soils
13	*E. tereticornis*	SFS	Australia	10.0°S - 35.0°S	140.0°E - 150.0°E	0 - 500	600 - 1200	15 - 30	Alluvial, loamy soils
14	*E. urophylla*	SAPPI	Australia	8.0°S - 12.0°S	125.0°E - 130.0°E	0 - 800	1200 - 2000	20 - 30	Sandy loam, volcanic
15	*E. camaldulensis*	ZFC	Australia	12.0°S - 24.0°S	120.0°E - 135.0°E	0 - 500	250 - 1200	15 - 30	Alluvial, sandy loamy
16	*E. cloeziana*	ZFC	Australia	18.0°S - 22.0°S	146.0°E - 150.0°E	200 - 900	700 - 1400	15 - 25	Sandy loamy
17	*E. tereticornis*	SF	South Africa	25^0S – 28^0S	30^0E – 32^0E	0 - 1000	500 - 1500	12C – 32	Alluvial soil, clay loam
18	*E. saligna*	Merensky	South Africa	25.0°S - 32.0°S	145.0°E - 150.0°E	0 - 1000	1200 - 2000	15 - 27	Loamy, well-drained soils
19	*E. grandis*	Merensky	South Africa	15.0°S - 28.0°S	30.0°E - 40.0°E	0 - 1500	1200 - 2500	15 - 27	Deep, fertile soils
20	*E. tereticornis*	TTSA	Tanzania	10.0°S - 35.0°S	140.0°E - 150.0°E	0 - 500	600 - 1200	15 - 30	Alluvial, loamy soils
21	*E. pellita*	TTSA	Tanzania	10.0°S - 14.0°S	145.0°E - 150.0°E	0 - 400	1200 - 2000	20 - 30	Loamy, well-drained soils
22	*E, tereticornis*	Mysore_SFS	India	12^0N – 13^0N	75^0E – 76^0E	0 - 800	700 - 800	15C – 35	Red sandy loam
23	*GC15*	GRL	South Africa	15.0°S - 28.0°S	30.0°E - 40.0°E	0 - 1500	1200 - 2500	15 - 27	Likely deep, fertile soils
24	*GC584*	GRL	South Africa	15.0°S - 28.0°S	30.0°E - 40.0°E	0 - 1500	1200 - 2500	15 - 27	Likely deep, fertile soils
25	*E. punctata*	CSIRO	Australia	27^0S – 33^0S	151^0E – 153^0E	100 - 1000	700 - 1400	15C – 30	Sandy loamy
26	*E. resinifera*	CSIRO	Australia	$^{-3}$0 ^{0}S– 34.5S	150^0E – 153^0E	0 - 1200	600 - 1200	10C – 20	Sandy loams, clay loams

Note: CSIRO = Commonwealth Scientific and Industrial Research; RSA = Republic of South Africa; ICFR = Institute for Commercial Forestry Research; TTSA = Tanzania Tree Seed A gency; KLF = Komatiland Forests; CSIR = Council for Scientific and Industrial Research; SAPPI = Sappi Southern Africa (Forestry & pulp/paper company); Mondi- 7 = Mondi (South A frica, "7" – trial code used by Mondi); ZFC = Zimbabwe Forest Commission; Merensky = Timber holding Company; GRL = Green Resources LTD; SFS = State Forest; Mysore_SFS = State Forest Services (Mysore/Karnataka); SF = Safcol Forestry; (GC 15 & GC 584) = *E. grandis* x *E. camaldulensi*

For the present study, five entries per genus were purposively selected for superior mid-rotation performance (Tables 1 and 2) [19]. Selection criteria included consistently high survival, growth performance, stem form, and apparent health status relative to other entries within each trial. This targeted selection was intended to focus the evaluation on the most operationally promising species/provenances likely to be considered for plantation deployment under coastal lowland conditions.

It is acknowledged that this purposive selection limits the scope of statistical inference and generalization beyond the selected entries. Consequently, comparisons are restricted to relative performance among these high-performing species/provenances rather than representing the full genetic or species diversity present in the original trials. Nonetheless, this approach is appropriate for operational forestry research aimed at identifying candidate species with superior mid-rotation wood properties, stem quality, and disease resistance under specific site conditions.

The selected *Corymbia* entries were *C. variegata* (CSIRO), *C. citriodora* (TTSA), *C. citriodora* (ZFC), *C. henryi* (CSIRO), and *C. henryi* (ZDL), with 80 trees planted per entry (Table 1). The selected *Eucalyptus* entries were *E. pellita* (SAPPI), *E. urophylla* (SAPPI), *E. urophylla* (CSIR), *E. camaldulensis* (TTSA), and *E. tereticornis* (SF), each represented by 96 trees (Table 2).

2.3. Data Collection

2.3.1. Wood Basic Density

Within each plot, two straight-stemmed trees were selected for wood sampling, representing the smallest and largest diameter classes among the 16 trees. One increment core was extracted from each selected tree at breast height (1.3 m above ground) using an increment borer to ensure consistency across samples. Immediately after extraction, the cores were wrapped in khaki corrugated paper, sealed with cellotape to prevent moisture loss, and transported to the laboratory.

In the laboratory, the cores were soaked in distilled water for at least 24 hours to restore green condition. Green volume was determined using the water displacement method [20]. The samples were then oven-dried at 103 ± 2°C to constant mass, cooled in desiccators, and weighed to determine oven-dry mass. Wood basic density (WBD) was calculated as the ratio of oven-dry mass to green volume [21]:

$$\text{WBD} = \text{Oven-dry weight (g)} / \text{Green volume (cm}^3\text{)} \quad (1)$$

2.3.2. Diseases Resistance

Disease resistance was assessed in the field using a standardized visual scoring protocol adapted from [13]. Each tree within a plot was individually evaluated for visible disease symptoms and assigned a binary score using a 0–1 scale. A score of 0 indicated no visible disease symptoms, while a score of 1 indicated clear evidence of disease presence. Symptoms assessed included stem lesions, cankers, defoliation, abnormal swellings, or kino exudation, all indicative of biotic stress. The number of affected trees per plot was recorded and used to estimate disease incidence.

2.3.3. Stem Quality Assessment

Table 3. *Criteria and scoring system used for rating tree stem quality at North Ruvu Forest Plantation, Pwani region in Tanzania.*

Score	Stem characteristics
1	Twisted
2	Poor straightness, long sweeps
3	Sweep, kinks in the main stem
4	Below average straightness
5	Above average straightness
6	Good straightness
7	Excellent straightness, small kinks, mainly crown stem
8	Excellent straightness

Source: TAFORI & TIRWG (2020)

Stem quality was evaluated visually using an eight-point scoring system following Standard Operating Procedures [22] (Table 3). Each tree within a plot was assessed individually and assigned a score from 1 (poor stem form) to 8 (excellent stem form). The assessment focused on key stem attributes influencing timber quality and processing efficiency, including straightness, bending, kinks, and forking. Mean stem quality scores were subsequently calculated at the plot level for statistical analysis.

2.4. Data Analysis

Data on wood basic density, stem quality, and disease resistance were analyzed for trees within the 55 assessed plots. Before analysis, all datasets were examined for normality using the Shapiro–Wilk test and for homoscedasticity using residual–fitted plots [23]. Where necessary, appropriate data transformations were applied.

Wood basic density was analyzed using an RCBD analysis of variance (ANOVA) model, with species/provenance treated as a fixed effect and block as a fixed blocking factor. The model was expressed as:

$$Yijk=\mu+\alpha i+\beta j+\varepsilon ijk \quad (2)$$

Where: $Yijk$ is the observed trait value for the ith species in the jth block, μ is the overall mean, αi is the effect of species/provenance βj: Effect of the jth Block (fixed factor, representing experimental replicates), βj is the block effect, and εijk is the random error term assumed to be normally distributed with mean zero and constant variance.

When significant treatment effects were detected ($\alpha = 0.05$), mean separation was performed using Duncan's Multiple Range Test (DMRT) with compact letter displays to identify homogeneous groups.

Stem quality scores were aggregated to plot-level means before analysis. Where ANOVA assumptions were satisfied, the same RCBD model and DMRT procedures were applied. When assumptions were violated despite transformation, non-parametric Kruskal–Wallis tests with adjusted multiple comparisons were used [24].

Disease resistance data were analyzed according to their measurement scale. Disease incidence was analyzed using a binomial generalized linear mixed model (GLMM), while count data were modeled using a negative binomial GLMM where overdispersion was present. Ordinal severity classes were analyzed using ordinal mixed models, and composite indices bounded between 0 and 1 were analyzed using beta regression models, with species/provenance treated as a fixed effect and block as a random effect [25].

All data were initially compiled in Microsoft Excel and subsequently analyzed using R version 4.3.2 (R Core Team, 2023) in RStudio, employing the packages *readr*, *readxl*, *dplyr*, *stringr*, *janitor*, *agricolae*, *broom*, and *tibble*.

3. Results

3.1. Wood Basic Density

Wood basic density differed significantly ($P < 0.05$) among *Corymbia* species (Table 4). Corymbia values ranged from 385 ± 18 kg m^{-3} (*C. henryi*, CSIRO) to 475 ± 27 kg m^{-3} (*C. citriodora*, TTSA).

Table 4. *Variation in wood basic density across different species/provenances of Corymbia and Eucalyptus planted at North Ruvu Forest Plantation, Pwani Region, Tanzania.*

Corymbia species/provenance	No. of trees sampled	WBD (kg m^{-3})	Eucalyptus species/provenance	No. of trees sampled	WBD (kg m^{-3})
C. citriodora_TTSA	10	475a ± 27	E. camaldulensis_TTSA	12	422a ± 11
C. henryi_ZDL	10	453a ± 17	E. pellita_SAPPI	12	401a ± 25
C. variegata_CSIRO	10	443a ± 16	E. tereticornis_SF	12	398a ± 11
C. citridora_ZFC	10	443a ± 12	E. urophylla_CSIR	12	395a ± 17
C. henryi_CSIRO	10	385b ± 18	E. urophylla_SAPPI	12	387a ± 7

*Means of individual species are presented with standard error (SE) in parentheses. For each genus, values followed by the same letter within a column are not significantly different at the 5% probability level.

In *Eucalyptus* species, mean wood basic density ranged from 386.6 ± 6.5 kg m^{-3} (*E. urophylla*, SAPPI) to 421.8 ± 10.0 kg m^{-3} (*E. camaldulensis*, TTSA), with no statistically significant differences detected among *Eucalyptus* entries ($P > 0.05$), despite variation in mean values (Table 4). This reflects a relatively uniform wood basic density response among the evaluated *Eucalyptus* species/provenances under the same site conditions.

3.2. Disease Resistance

Disease incidence varied among species and provenances (Table 5). Among Corymbia species, disease incidence ranged from 0% (*C. citriodora*, TTSA and ZFC) to 27.8% (*C. henryi*, ZDL).

Table 5. *Disease incidence among selected Corymbia and Eucalyptus species at North Ruvu Forest Plantation, Pwani Region, Tanzania.*

Name of Species/provenances	No. of trees sampled	Frequency of infestation	Infested trees (%)
C. henryi_ZDL	18	5	27.8
C. henryi_CSIRO	23	5	21.7
E. tereticornis_SF	24	4	14.3
E. pellita_SAPPI	14	1	7.1
E. urophylla_CSIR	18	1	5.6
C. variegata_CSIRO	20	1	5
E. urophylla_SAPPI	21	1	4.8
C. citriodora_ZFC	15	0	0

Name of Species/provenances	No. of trees sampled	Frequency of infestation	Infested trees (%)
C. citriodora_TTSA	12	0	0
E. camaldulensis_TTSA	19	0	0

In *Eucalyptus* species, disease incidence ranged from 0% (*E. camaldulensis*, TTSA) to 14.3% (*E. tereticornis*, SF), with generally low and comparable infection levels across entries, despite differences in observed percentages (Table 5). Several *Corymbia* and *Eucalyptus* entries showed no disease symptoms.

3.3. Stem Quality

Stem quality varied among species and provenances. In Corymbia, the proportion of high-quality stems ranged from 92% (*C. citriodora*, TTSA) to 100% (*C. variegata*, CSIRO) (Figure 2).

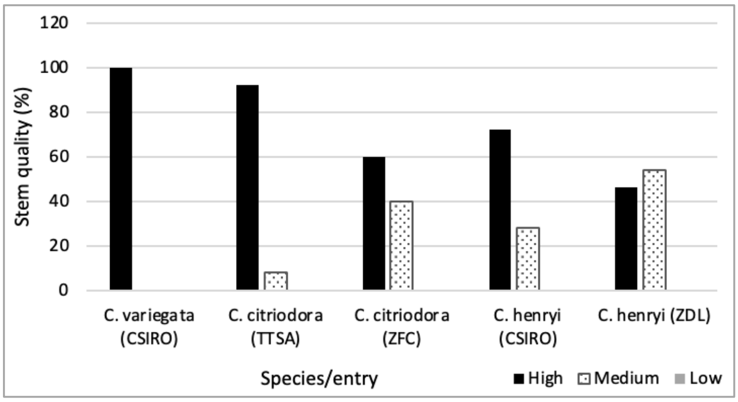

Figure 2. *Stem quality distribution of Corymbia species at North Ruvu Forest Plantation, Pwani Region, Tanzania.*

In *Eucalyptus* species, *E. tereticornis* (SF), *E. urophylla* (CSIR), and *E. urophylla* (SAPPI) each recorded more than 60% high-quality stems, indicating broadly acceptable and relatively consistent stem quality among Eucalyptus entries, despite variation in individual proportions (Figure 3).

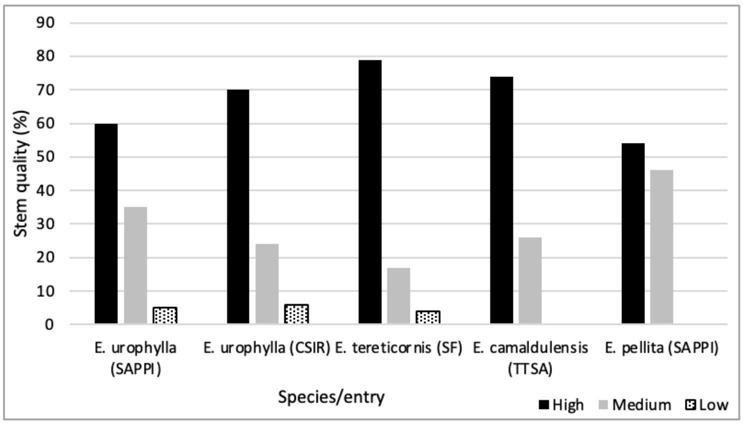

Figure 3. *Stem quality distribution of Eucalyptus species at North Ruvu Forest Plantation, Pwani Region, Tanzania.*

4. Discussion

Species performance at North Ruvu showed significant differences between *Corymbia* and *Eucalyptus*, confirming that plantation success at this coastal site depends more on species–site compatibility than broad genus classification

[33]. The consistently better performance of *Corymbia citriodora* and *Corymbia variegata* reflects their close match with local conditions, sandy soils, periodic moisture shortages, and exposure to coastal winds. These conditions favor species that invest in structural stability and stress tolerance rather than fast early growth [27].

Differences in wood basic density (WBD) explain much of this ecological performance. Higher WBD in *Corymbia* indicates greater investment in lignified tissues and secondary cell walls, enhancing mechanical strength and resistance to hydraulic stress under coastal conditions [27, 29]. In contrast, the generally lower WBD in *Eucalyptus* reflects a growth-focused strategy aimed at rapid fiber production [31]. While advantageous in high-input or short-rotation systems, this approach may reduce resilience on marginal coastal sites where nutrients and water are limited [26, 28, 30].

Patterns of disease incidence further illustrate species suitability at North Ruvu. The lack of visible symptoms in *C. citriodora* and *E. camaldulensis* (TTSA) indicates effective inherent resistance under current pathogen loads, an important advantage in humid coastal environments prone to episodic stress [35, 36]. Conversely, higher disease incidence in certain provenances, particularly *C. henryi*, reflects ecological mismatch and strong genotype-by-environment interactions, emphasizing that disease resistance depends on both species and site [38, 40].

These health-related differences align with stem quality outcomes, showing how multiple traits combine to determine overall suitability. *C. citriodora* and *C. variegata* consistently demonstrated superior stem straightness and form, indicating strong apical dominance and mechanical stability [41-43]. Higher wood density likely contributed to increased stem stiffness, reducing deformation from wind and improving the proportion of merchantable stems [29, 34]. Poorer stem form in many *Eucalyptus* entries corresponds with faster juvenile growth, increasing susceptibility to sweeping and forking before adequate structural support develops [44].

Overall, high-performing *Corymbia* species combine dense wood, good stem form, and effective disease resistance into a cohesive functional package well suited to coastal stresses [33, 34]. *Eucalyptus* species occupy a different niche, prioritizing rapid growth and fiber yield but with less structural robustness under the same conditions [31, 44]. These functional differences provide clear guidance for species selection and highlight the importance of precise species–site matching in Tanzanian coastal plantations [32, 33].

5. Conclusion

The results indicate that *Corymbia* species, particularly *C. citriodora* and *C. variegata*, are better suited to North Ruvu's environmental conditions than the tested *Eucalyptus* species. Their superior performance across wood basic density, stem quality, and disease resistance reflects combined adaptive traits that enhance resilience to sandy soils, wind exposure, and episodic moisture shortages. These traits make *Corymbia* promising candidates for diversifying Tanzania's coastal plantations toward higher-value structural timber production.

Although *E. camaldulensis* performed well for some traits, *Corymbia* is overall favored for long-term stability and wood quality on similar sites. It is important to note that this study did not assess growth rates, yields, or economic returns; thus, recommendations for large-scale planting are based solely on the traits evaluated here.

6. Recommendations

Given their combined trait advantages, *C. citriodora* and *C. variegata* should be prioritized for pilot and commercial planting in Tanzania's coastal dry tropics, especially where durable sawlogs and poles are the objective. Their structural durability and disease tolerance position them well to handle typical coastal plantation challenges.

Future research should evaluate growth performance, biomass accumulation, and economic returns alongside wood quality and disease resistance. Such comprehensive assessments will better inform productivity, profitability, and long-term sustainability.

Considering ongoing pest and disease risks in coastal areas, long-term monitoring of pathogen incidence and resistance is recommended. Continuous assessment will help anticipate emerging threats and guide adaptive management for both *Corymbia* and *Eucalyptus* plantations.

Forest managers and policymakers should use multi-trait evaluation frameworks for species selection. By emphasizing species–site matching based on performance traits, plantation resilience can be improved, climate change risks reduced, and sustainable forestry supported in Tanzania.

Abbreviations

ANOVA	Analysis of Variance
CLD	Compact Letter Display
DMRT	Duncan Multiple Range Test
FDT	Forest Development Trust
GLMM	Generalized Linear Mixed Model
RCBD	Randomized Complete Block Design
TFS	Tanzania Forest Services Agency
TAFORI	Tanzania Forest Research Institute
TIRWG	Tree Improvement Research Working Group
URT	United Republic of Tanzania
WBD	Wood Basic Density

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Conflicts of Interest

The authors declare no conflicts of interest.

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