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Derris microphylla: A Potential Alternative High Shade Tree Species for *Albizia moluccana* (AKA: *Falcataria moluccana*) in Low Grown Tea Fields in Sri Lanka

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ABSTRACT
Shade harmonizes micro-climatic environmental factors favorable for tea. Presently, growers use *Albizia* for this purpose in low and mid elevations. However, its fast growth and large size have caused difficulties in shade management. This observation led the Tea Research Institute of Sri Lanka (TRISL) to identify an alternative tree species to *Albizia.* Hence, the main objective of this study was to test the growth performances of alternative high shade tree species and study their effect on the growth and yield of tea. The experiment was established in Houpe Estate, Kahawatte with two new high shade tree species *viz., Derris microphylla* and *Cassia nodosa* planted at 3 planting distances (6x6 m, 9x9 m and 6x9 m). The control treatment was *Albizia moluccana* planted at 6x6 m. Treatments were arranged in Randomized Complete Block Design (RCBD) with 3 replicates. The growth of shade and tea, tea yield and soil parameters were recorded over a period of four years. Height of *C. nodosa* was found to be inadequate, as a high shade tree in tea. Its trunk was thinner than *A. moluccana* but, profuse branching necessitated more frequent lopping. Other unfavorable characteristics of *C. nodosa* included high mortality rates, spiky trunk, and defoliation during dry weather, where tea requires shade the most. *D. microphylla* exhibited smaller girth and height than *A. moluccana*, resulting in a more manageable stature for routine maintenance. Other growth characteristics of *D. microphylla* and its influence on tea yield were comparable to those of *A. moluccana* (control) and showed no pest or disease infestations. Soil parameters under *A. moluccana* and *D. microphylla* were also comparable. Therefore, *D. microphylla* could be considered as a potential alternative to *A. moluccana* in the establishment and management of high shade in tea at low elevation.

Keywords: *Albizia moluccana,* alternative tree species, *Derris microphylla*, micro-climatic environmental factors, shade in tea

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INTRODUCTION

Shade trees first came into commercial tea plantations in 1800's (Dutta, 1961) by accident when Assam teas flourished better under *Albizia chinensis* which had been leftover in forest clearing and grown with tea. Since then, shade trees in tea plantations became a general practice in order to stimulate natural forest conditions for the optimal growth and yield of tea (Beer, 1987).

Since, tea (*Camellia sinensis* (L.) O. Kuntze) originated in humid tropical forests under *Albizia* trees, it evolved into a shade loving plant and therefore, partial shade is considered essential for its growth (Carr and Stephens, 1992). Shade trees control micro-climate and provide a number of advantages for the betterment of tea crop such as, attenuating solar radiation and ambient temperature, increasing relative humidity, acting as a wind barrier, conserving soil moisture, in addition to supplying soil organic matter, soil nutrients (Wijeratne *et al*., 2016 and Wijeratne *et. al.,* 2007) and mitigating drought effects (Duncan *et al*., 2016).

Maximum photosynthetic capacity in tea leaves occurs around 30-35 ^{o}C of leaf temperature (Hadfield, 1975) which begins to drop beyond 37 ^{o}C and cease at around 42 ^{o}C (Rahman, 1988). Under tropical conditions (e.g. Sri Lanka), mid-day temperature exceeds the optimum level for photosynthesis (Sivapalan, 1993) when internal leaf temperature rises 2-12 ^{o}C above the ambient (Rahman, 1988). Further, intense light conditions trigger photo-inhibitory mechanisms and decline net photosynthesis (Mohotti and Lawlor, 2002). Shade cuts down light intensity and reduces leaf temperature by around 10-12 ^{o}C below the ambient (Gee *et al*., 1982). Thereby, shade controls micro-climatic parameters and harmonizes internal physiological processes such as stomatal conductance, photosynthesis, respiration and transpiration and eventually maximizes growth and tea yield (Mohotti and Lawlor, 2002).

A well-managed *Albizia* cover can cut down around 40 % solar radiation and maintain micro-climatic air temperature below 30 ^{o}C. This supports a maximum photosynthetic rate while improving yield components (average shoot weight and shoot density) (Wijeratne *et. al.,* 2007). In addition, optimum range of shade assures a better composition in bio-chemical compounds (Wang *et al.,* 2012) and higher leaf chlorophyll content (Rajkumar, *et al*., 2002) enhancing quality of made tea. However, more than 40 % shade level decreases photosynthetic rate due to excessive shielding of Photosynthetically Active Radiation (PAR) (Wijeratne *et al*., 2016). Therefore, both establishment and proper management of shade is crucial for a sustainable tea cultivation, as both excessive shade and excessive light (full sunlight) can adversely affect the growth of tea particularly in low grown conditions where frequent high temperature and drought conditions prevail, especially in present climate change conditions.

Presently tea estates are facing about 25-49 % scarcity of work force which is much severe in low country tea estates (Shyamalie *et al.*, 2016). This situation has affected all the field operations including shade management. Tea growers frequently complain that they find practical difficulties in replacement of shade trees in short intervals as 10-12 year cycle as recommended by the TRISL (Anon, 2003) as it involves considerable labour and cost. In this scenario, tea growers pay less attention to establishment and management of high shade and timely replacement of existing shade trees. As a result, *A. moluccana* grows into excessive height and girth and becomes unmanageable after which, they are usually cut and sold for timber. Removal of over-grown *Albizia* trees results in physical damage to tea bushes due to falling of large trees on to the canopy (Personal communication) and physiological damage with the exposure of tea canopy into full sunlight and eventually resulting in low yield. Therefore, an industry need was identified for alternative high shade tree species which grows smaller and can serve a longer period than *A. moluccana* in low country tea fields while providing shade effectively.

D. microphylla (Fabaceae) is a tree with a high regenerating capacity and grows up to about 10-20 m in height with its trunk about 25-30 cm in diameter. Horizontally spreading branches of this tree bear imparipinnate leaves of about 20 cm long. Purple flowers are arranged in an inflorescence and produce flat pods with 2-5 seeds inside. Shallow and spreading root system of this plant is known to minimize soil erosion while its tap root and flexible trunk withstand wind. Therefore, *D. microphylla* is used as a shade tree in tea, coffee and cocoa plantations (Anon, 2022[a]), in some other countries. *Cassia nodosa* is another tree in family Fabaceae and grows up to about 10-20 m in height. Slender branches of this tree grow horizontally and produce imparipinnate leaves of about 20-30 cm long. Pink flowers are in an inflorescence and produce 30-70 cm long cylindrical pods. This plant is also used to provide shade in plantations (Anon, 2022[b]).

The main objective of this study was to investigate growth performances of these potential high shade tree species and to study their effect on the growth and yield of tea in Sri Lanka.

MATERIALS AND METHODS

The experiment was established in the Yayinna Division of Houpe Estate, Kahawatta (6.56^0 N, 80.52^0 E / 30 m *amsl* / WL2a / > 2400 mm yr^{-1}) in 2014. In this experiment, two potentially suitable high shade tree species (*Derris microphylla* and *Cassia nodosa - short listed after evaluating growth and canopy characteristics of a large number of tree species*) were tested in comparison with *Albizia moluccana*; the existing recommendation for low grown tea (Plate 1). High shade trees (raised in poly bags) were initially established with three different spacing *viz*., 6x6 m, 9x9 m and 6x9 m. Tea cultivar used in the experiment was TRI 4042 (at 0.6x1.2 m spacing) and *Gliricidia sepium* (at 3x3 m spacing) was established as the medium shade tree in all plots. Tea plants were fertilized with T200 mixture during the first two years and with T750 from 3rd year onward and plucked at weekly intervals. Other field operations were continued as recommended by the TRISL. Made tea yield for the third and fourth year after planting was estimated by using a conversion factor of 4.65 (1kg of made tea = green leaf yield/4.65). In the 4th year after planting (2018), all high shade trees initially planted at 6x6 m distances were thinned out to 12x12 m as recommended by the TRISL. Other two planting spaces (9x9 m and 6x9 m) were kept unchanged for the purpose of comparing with recommended planting density. Growth of shade trees were managed (annual lopping of branches) where necessary to avoid excessive shade. This paper discusses the results obtained before the thinning out operation.

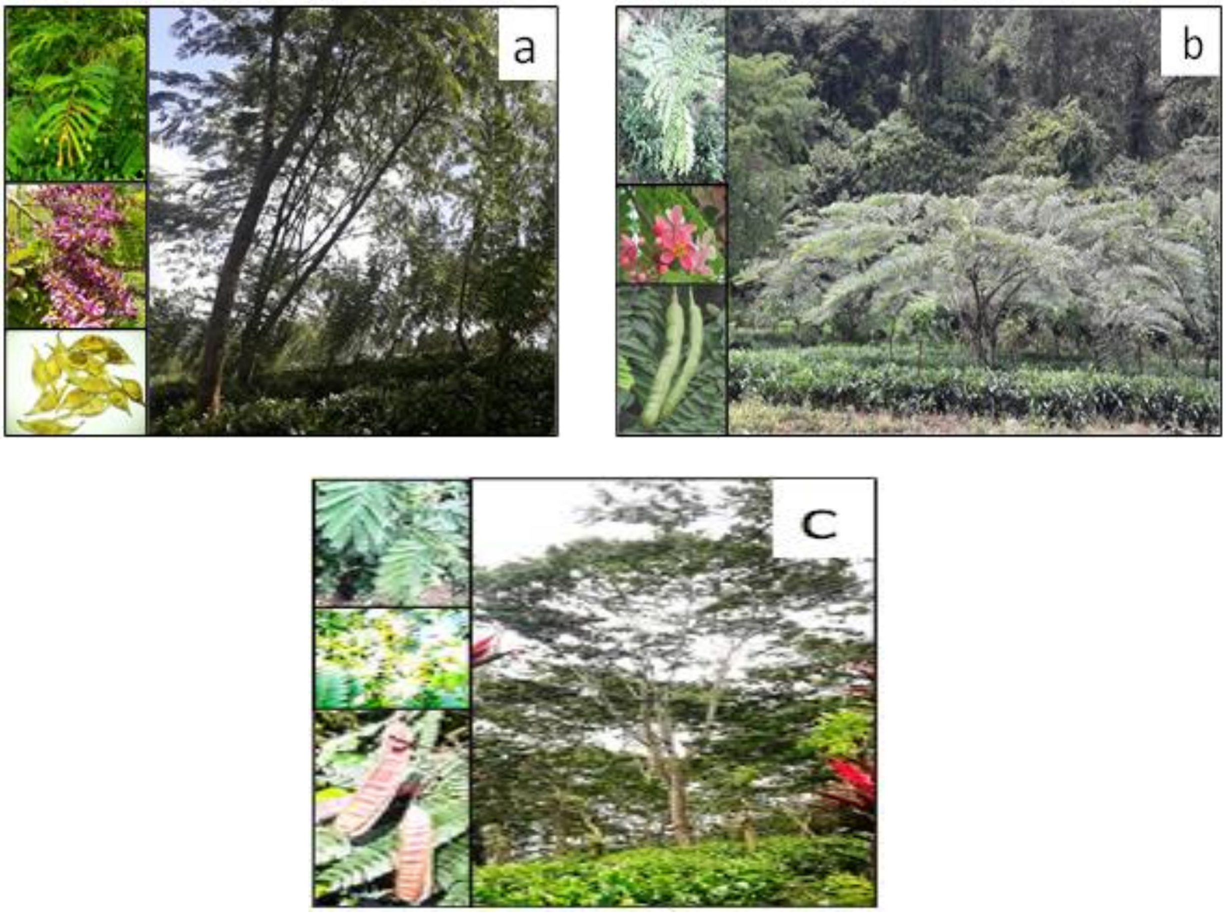

Plate 1. Leaflets, flowers, pods and trees of (a) *Derris microphylla*, (b) *Cassia nodosa*, *and* (c) *Albizia moluccana.*

Different shade regimes tested are shown in the Table 1. They were arranged in RCBD in 3 replicates and established separately in 21 plots each of which was about 1200 m^2.

Table 1. Different shade regimes and their respective treatment codes

Treatment Number	High-Shade Tree Species	Planting Distance (m)	Treatment Code
T1	*Derris microphylla*	6x6	(DM-6x6)
T2	*Derris microphylla*	9x9	(DM-9x9)
T3	*Derris microphylla*	6x9	(DM-6x9)
T4	*Cassia nodosa*	6x6	(CN-6x6)
T5	*Cassia nodosa*	9x9	(CN-9x9)
T6	*Cassia nodosa*	6x9	(CN-6x9)
T7	*Albizia moluccana*	6x6	(AM-6x6) Control)

Growth of the shade trees were recorded as; total plant height (m), height at 1st branching, trunk girth at ground level (cm), trunk girth at chest height (1.25 m above ground level) (cm), number of secondary branches. In addition, the canopy spread (m) was measured as the average diameter of foliage canopy. In tea, girth (cm) of the main stem (at ground level) was recorded in addition to the fresh shoot yield (kg).

In the soil, total nitrogen content (N) was determined by Kjeldhal method as described by Bermnar (1982). Phosphorous (P), potassium (K) and pH were determined as described by Dharmakeerthi *et al*. (2007) and the organic carbon (C) content was determined following the method described by Walkey and Black (1934). All above measurements were recorded 4 years after planting. In the dry season (February 2018) soil samples were collected from two depths (0-15 cm and 15-30cm) and they were analysed using gravimetric measurements in standard laboratory procedures for moisture contents.

Data analysis was done using SAS (v.9.1) statistical package where continuous data (weights and heights) were analysed with ANOVA followed by LSD mean separation. Counts and percentages were analysed using CATMOD and PROBIT procedures.

RESULTS AND DISCUSSION

Growth of high shade trees

Four years after planting, total height of *A. moluccana* (control) was significantly (ρ=0.05) higher (18 m) than both *D. microphylla* and *C. nodosa* irrespective of different planting distances (Figure 1a). Total plant height and height to the first branching point (Figures 1a & 1b) in *D. microphylla* were about 10 m and 4 m, respectively. This growth can be considered as satisfactory in this age of shade trees. Further, due to low canopy establishment, newly tested *D.microphylla* can be easily managed when compared with *A.moluccana*. However, height of *C.nodosa* was only about 5 m which was inadequate as a high shade tree in tea.

The number of secondary branches produced by *D.microphylla* was comparable (ρ=0.05) with that of *A.moluccana*, irrespective of planting distances (Figure 1c). Contrarily, *C.nodosa* rapidly produced a large number of branches casting thick shade which were to be lopped 2-3 times per year requiring extra effort to manage shade and provide adequate sun light for tea.

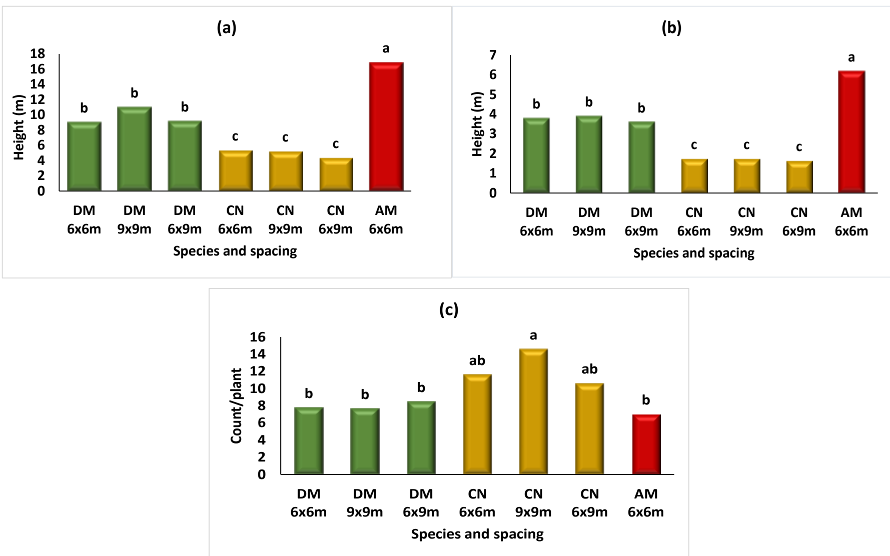

Figure 1. Growth of high shade trees (a) Total plant height (b) Height at the first branching (c) Count of secondary branches per plant.

Bars with the same letter(s) in same graph are not significantly different at ρ=0.05.

Table 2. Shade tree trunk girth (diameter)

Treatment	At ground level (cm)	At chest height* (cm)
DM-6x6	22.20^{b}	19.60^{bc}
DM-9x9	25.80^{b}	22.97^{b}
DM-6x9	22.90^{b}	19.63^{bc}
CN-6x6	20.23^{b}	15.83^{c}
CN-9x9	22.67^{b}	15.63^{c}
CN-6x9	20.77^{b}	15.27^{c}
AM-6x6	47.77^{a}	37.90^{a}
CV%	14.48	12.7

Values in the same column with the same letter(s) are not significantly different at ρ=0.05.

* - 1.25 m above ground level

Girth of *A.moluccana* (6x6 m) was significantly higher (*ρ*=0.05) than that of *D.microphylla* and *C.nodosa* irrespective of different planting distances tested (Table 2). Excessive trunk girth was one of the reasons for tea growers' complaints about *A.moluccana* and difficulty in shade management. Therefore, newly tested high shade trees with smaller trunks exhibited promising characteristics compared with the present recommendation.

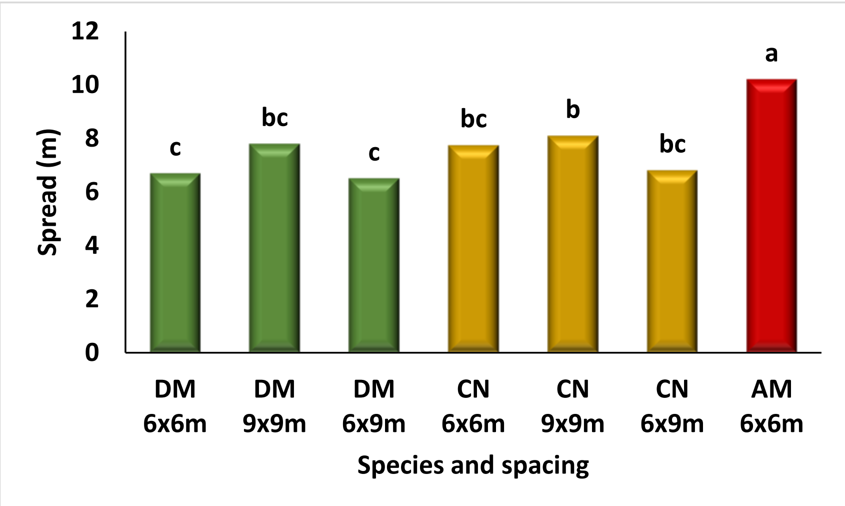

Figure 2. Canopy spread (diameter) of different high shade tree species.
Bars with the same letter(s) are not significantly different at ρ=0.05.

A. moluccana showed the largest (*ρ*=0.05) canopy spread (diameter) compared to both *C. nodosa* and *D. microphylla* irrespective of the planting distances, yet canopies of the latter two species has grown adequately to cover inter-spaces between plants (Figure 2). Though, *D. microphylla* was to be pruned in similar intervals as for *A. moluccana*, in order to provide proper shade to tea *C. nodosa* required frequent pruning due to its excessive proliferation of branches as discussed earlier. Therefore, the canopy spread observed in *D. microphylla* was found to be more suited as a high shade for tea.

Effect on growth and yield of tea

Table 3. Tea trunk girth (diameter)

Treatment	Girth (cm)
DM-6x6	4.90[a]
DM-9x9	4.93[a]
DM-6x9	5.70[a]
CN-6x6	5.23[a]
CN-9x9	5.70[a]
CN-6x9	4.63[a]
AM-6x6	4.56[a]
CV%	10.05

Values with the same letter(s) are not significantly different at ρ=0.05.

Growth of young tea can be adversely affected by both excessive shade and excessive sunlight. Therefore, proper management of high shade is extremely important in low grown teas where high temperature and drought conditions are prevailed especially with present climate change conditions. Table 3 shows comparable (*ρ*=0.05) growth (girth) of tea under all shade regimes (species & spacing) with proper shade management. Therefore, shade provided by *D. microphylla* and *C. nodosa* regimes has provided favourable environment for the growth of tea bushes similar to that of *A. moluccana*.

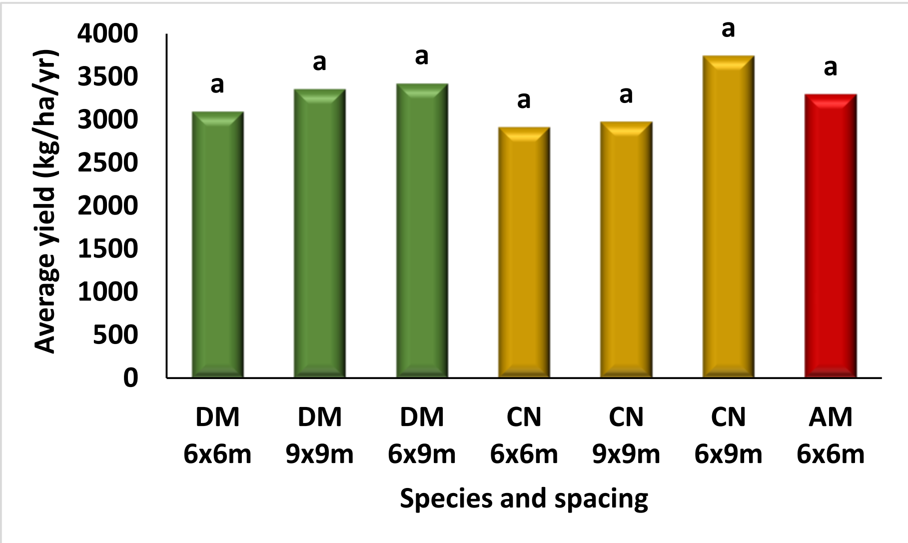

Figure 3. Average made tea yield during the 3rd & 4th years after planting as affected by different shade regimes.

Bars with the same letter(s) are not significantly different at ρ=0.05.

As mentioned earlier, proper shade harmonizes internal physiological processes and results in maximum growth and yield of tea. Figure 3 shows the average made tea yield of young tea (during 2017 & 2018) under different shade regimes. Accordingly, all new shade regimes (species and spacing) have given comparable (*ρ*=0.05) tea yields to that of *A.moluccana* (6x6 m).

Effect on the soil properties

None of the soil nutrients measured (both at 0-15 cm and 15-30 cm soil depths) showed significant (ρ=0.05) variation among treatments except total nitrogen content at 0-15 cm soil depth. At the 0-15 cm soil depth, all the tested planting densities of *D. microphylla* shade trees reported soil N levels comparable to those under the *A. moluccana* shade regime. Further, soil nutrients and organic carbon contents (C %) presented in Table 4 & 5 fall within the normal range of low country tea soils (Liyanage *et al*., 2014). Moreover, none of the shade regimes significantly affected soil pH levels that they all were in the favourable range for tea (Anon., 2000).

Table 4. Soil properties measured at 0-15 cm depth

Treatment	pH	C (%)	N (%)	K (ppm)	P (ppm)
DM-6x6	5.07^{a}	1.37^{a}	0.208^{abc}	134.5^{a}	18.63^{a}
DM-9x9	5.05^{a}	1.41^{a}	0.210^{ab}	139.1^{a}	20.27^{a}
DM-6x9	4.84^{a}	1.82^{a}	0.208^{abc}	120.6^{a}	21.40^{a}
CN-6x6	5.02^{a}	1.39^{a}	0.221^{a}	143.2^{a}	22.53^{a}
CN-9x9	4.94^{a}	1.55^{a}	0.191^{c}	134.5^{a}	21.17^{a}
CN-6x9	4.89^{a}	1.59^{a}	0.219^{a}	144.6^{a}	22.70^{a}
AM-6x6	4.94^{a}	1.66^{a}	0.201^{bc}	135.8^{a}	22.40^{a}
CV	3.05	13.39	4.91	10.95	16.4

Values in the same column with the same letter(s) are not significantly different at ρ=0.05.

Table 5: Soil properties measured at 15-30 cm depth

Treatment	pH	C (%)	N (%)	K (ppm)	P (ppm)
DM-6x6	4.88^{a}	1.34^{a}	0.200^{a}	141.0^{a}	21.13^{a}
DM-9x9	4.92^{a}	1.44^{a}	0.210^{a}	125.3^{a}	20.60^{a}
DM-6x9	4.68^{a}	1.36^{a}	0.200^{a}	131.2^{a}	22.33^{a}
CN-6x6	4.94^{a}	1.38^{a}	0.198^{a}	137.5^{a}	21.07^{a}
CN-9x9	4.71^{a}	1.43^{a}	0.210^{a}	134.4^{a}	21.02^{a}
CN-6x9	4.86^{a}	1.38^{a}	0.198^{a}	143.8^{a}	18.33^{a}
AM-6x6	4.95^{a}	1.47^{a}	0.205^{a}	130.7^{a}	21.07^{a}
CV	4.87	9.47	7.04	11.37	11.20

Values in the same column with the same letter(s) are not significantly different at ρ=0.05.

Gravimetric measurements of soil moisture percentage at two different soil depths representing root zone of tea are depicted in Figure 4.

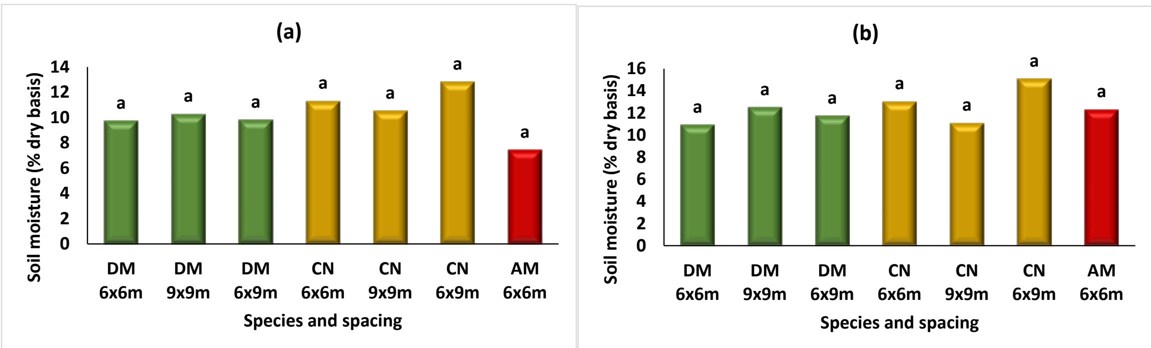

Figure 4. Soil moisture content during dry season: (a) at 0-15 cm depth, (b) at 15-30 cm depth.

Bars with the same letter(s) in same graph are not significantly different at ρ=0.05.

Shade trees should have a minimum competition with tea for common resources. Since, low grown teas are subjected to drought conditions more frequently, effect of new shade regimes on dry season soil moisture conditions is of utmost importance. Soil moisture contents (both at 0-15 and 15-30 cm depths) under *D. microphylla* and *C. nodosa* high shade regimes were comparable (ρ=0.05) to those under *A. moluccana*. With the results, it can be assumed that new shade tree species have not competed with tea for soil moisture.

Other field observations and summary of the findings

As mentioned earlier, *A. moluccana* becomes unmanageable in 10-12 years due to its excessive size (height and trunk girth) which is the major reasons for tea growers pay less attention to it, as climbing larger trees for lopping of branches is a tedious task requiring more labour and greater skills. This study found that both *D. microphylla* and *C. nodosa* with shorter and thinner trunks compared with *A. moluccana* to provide amenable solutions for this practical problem. It is also interesting to note that, *D. microphylla* recorded no pest and disease attacks and also gave less than 5 % casualties during the experimental period. Further, observations by the authors in other locations have shown that *D. microphylla* maintains manageable heights and girths at least 20-25 years after planting (Anon., 2018).

Overall observations show that, *D. microphylla* can be considered a promising alternative for *A. moluccana* as a high shade tree in low grown tea with longer effective lifespan (without becoming unmanageable) and comparable benefits to that of *A. moluccana* on growth and yield of tea.

However, *C. nodosa* was less suitable as a high shade tree for tea. Its inadequate plant height and aggressive branching habit casted thick shade requiring more frequent lopping and attention than *A. moluccana.* Additionally, *C. nodosa* is heavily subjected to porcupine-attacks and susceptible to collar-canker resulting high incidence of casualties. Further, presence of large spines on the trunk and dry weather leaf fall of *C.nodosa* were also found to be undesirable characteristics of a high shade tree in tea.

CONCLUSIONS

Growth characteristics of *Derris microphylla* are more suitable as a high shade for tea than those of *Albizia moluccana.* Growth and yield of tea established under *Derris microphylla* shade is similar to those of tea under presently recommended *Albizia moluccana.* There were no reports of pest and disease attacks on *D.microphylla* and it is easily manageable in tea fields. Therefore, *Derris microphylla* can be identified as a potential alternative high shade tree species for *Albizia moluccana* in low grown tea plantations.

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