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Above and below ground biomass estimation of *Acacia mangium* Willd in instructional farm of forestry, Navsari agricultural university, Navsari

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Abstract

The present study was conducted to estimate biomass of above and below ground parts of *Acacia mangium* Willd plantation. For this eight year old plantation stand at instructional farm of forestry in Navsari agricultural university Navsari has a density of around 400 individuals in 0.25 ha area and a top height of 25.85 m, DBH of tree ranged from 4.5 to 31.75 cm and average 18.20 cm was selected and destructive sample was carried out with seven diameter classes, consist of three individuals in each diameter class. Above ground biomass of tree was measured in three component viz., leaves, branch and trunk while below ground biomass in primary roots and secondary roots.

The biomass studies of above ground parts recorded the maximum in 30-35 cm DBH resulted 685 Kg dry biomass per tree which was composed of 104.25 Kg of leaves, 124.28 Kg of branch wood and 456.49 Kg of main trunk while highest below ground dry biomass of one cubic meter root skeleton was 125 Kg/tree comprised of 101.83 Kg of primary roots and 23.18 Kg of secondary roots. Total tree biomass as fresh (1092.09 Kg/tree) and dry (810.02 Kg/tree) biomass was recorded. The proportion of above ground and below ground biomass to total biomass on dry weight basis varied from 84.00% to 92.14% and 7.40% to 16.00% respectively.

Keywords: Above, below ground biomass estimation, *Acacia mangium* Willd in instructional farm

Introduction

Acacia mangium Willd commonly known as Brown sal wood, Australian teak, Lickony Wattle, Black Wattle, Hickory Wattle, and Mangium is a promising fast growing, evergreen leguminous tree belongs to family Fabaceae (subfamily Mimosaceae). It is native of north-eastern Queensland in Australia, the Western Province of Papua New Guinea, and Indonesia with distributional latitudinal range from 1° to 18º57'S and longitudinal range from 125º22' to 146º17'E. The mean altitudinal range is from just above sea level to 780m. Distribution of Mangium is strongly influenced by rainfall patterns and soil drainage. It prefers wet sites with an annual rainfall of 1,000-4,500 mm. This species can grow even in acidic soils with pH as low as 4.2. This tree is useful for shade, avenue, screening, boundaries and wind breaks along with agroforestry and erosion control. The leaves partially used for livestock fodder and branches with dry leaves are gathered for fuel. Its wood has a good caloric value and used for the production of coal briquettes. Apart from that, the timber used as construction wood, for furniture or even for veneers. The cellulose produced by *A. mangium* can be bleached easily and is fit for high quality paper.

Acacia mangium is described as a multi-purpose fast-growing tree species for the humid tropics, has a straight trunk, can attain a mean annual diameter increment at breast height up to 5 cm and mean annual height increment of 5 m in the first four to five years. However growth declines rapidly after seven or eight years, except under very ideal conditions over long periods (above 20 years). The mature tree has 35 cm dbh and 35 m height. A tree of 20 cm DBH can give a volume of 0.185 m^3 to 0.220 m^3 with a biomass of 160 to 183 Kg (Lim, 1993).The growth rate of *Acacia mangium* in Malaysia for trees of 9 years age, a height of 23 m and an average increase in diameter of 2-3 cm per year are reported. Annual growth yield reported is 46 m^3 per hectare. Average stands of 4 year old trees annually produce 27 m^3wood per hectare. In 14 years it grows up to 30 m height and 40 cm in diameter (DBH) (NRC, 1983) [5].

Studies carried out by KFRI, Peechi, India revealed an average girth at breast height (GBH) of 112 cm for trees of age 10 years with mean annual increment (MAI) of GBH 11 to 18 cm. The mean height of the trees varies from 4 m to 9 m at the age of 1 year, to 26.2 m at the age of 10 years with MAI range of 1.8-6.1 m.

In this study, we examined the accumulation of aboveground biomass based on growth data in eight year old *Acacia mangium* plantation.

Acacia species have shown tremendous growth performance in many research sites and provenance trials (Thinh *et al*., 1998; Bino, 1998) [9, 1].

Material and Methodology

2.1 Materials

2.1 .1 Description of study area

The present investigation entitled "Studies on below ground interaction and carbon sequestration in *Acacia mangium* Willd plantation". was carried out in 2013-2015 at the Instructional Farm, ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari (20^0 92' N, 72^0 88' E). In year 2013-2015.

2.1.2 Climate and Weather

Navsari district is located in the south eastern part of Gujarat state and situated at 20^0 94' N latitude, 72^0 91' E longitude and at an altitude of 10 meter above the mean sea level. The climate is typically tropical characterized by fairly hot summer, moderately cold winter and warm humid monsoon. Generally, monsoon in this region commences in the second week of June and ends in September. Most of the precipitation is received from South West monsoon, concentrating in the months of July and August. Average annual rainfall of this region is about 1806 mm (1992-2011).

2.1.3 Soil features Navsari region

As per the soil taxonomical classification, soil of Navsari has been placed under the great group of chromusterts, sub group typic chromusterts, sub-order asterts and order vertisols with Eru series. The soil has predominantly montmorillonitic type of clay soil (Kaswala and Despande, 1983) [4]. The average pH of the soil is 7.8.

2.1.4 Treatment and replication used for above and below ground biomass estimation.

Seven diameter classes were used as treatment. For each treatment, three trees (replication) were marked and used for present study.

T_1 = < 5 cm Dia., T_2 = 5-10 cm Dia., T_3 = 10- 15 cm Dia., T_4 = 15- 20 cm Dia., T_5 = 20- 25 cm Dia., T_6 = 25- 30 cm Dia., T_7 = 30- 35 cm Dia.

2.2 Methodology

2.2.1 Estimation of above and below ground biomass

The above and below ground biomass estimated through destructive method. From the selected seven diameter classes 21 trees were cut such that three trees from each diameter classes i.e. 3x7=21. After recording the total height, crown height, crown width, bark thickness and diameter at breast height, the trees were felled at ground level by bow saw by retaining stumps. The trunk is separated into 12 ft logs (3 m) up to the 20 cm over bark diameter (only in last three classes) and fresh weight was recorded. The above ground portions were separated into trunk wood, branch wood and foliage. Fresh weight of the entire tree component was separately recorded immediately after felling using spring balance for branch wood & foliage and electric balance for wood. Representative foliage, branch wood and trunk wood was collected for moisture content estimation.

To measure the below ground biomass, roots were dug up by framing one cubic meter skeleton around tree trunk and biometrical observation of roots parameter like length of primary roots, circumference of primary roots, no. of secondary roots, length of secondary roots and circumference of secondary roots was recorded. After reporting of biometrical observation root with stump was extracted from soil and then root weight (fresh & dry) of all the felled trees was recorded. Weight of root was measured by spring hanging balance and root sample was collected immediately after uprooting for moisture estimation.

Result and Discussion

3.1 Above ground fresh and dry biomass

Variation in above ground fresh and dry biomass (Kg/tree) among different diameter classes in *Acacia mangium* was recorded for trunk, branch wood, leaves and whole tree. Details of results are tabulated in 3.1 and 3.2 and graphically presented in Fig. 3.1. Fresh and dry biomass accumulation was more in trunk then branch and leaves. In trunk fresh and dry biomass increase from 8.96 'F' and 7.37 'D' Kg/tree in diameter class T_1 to 554.59 'F' and 456.49 'D' Kg/tree in diameter class T_7 whereas, in branch and leaves it increase 1.08 'F', 0.71 'D' Kg/tree and 2.73 'F', 1.94 'D' Kg/tree respectively in diameter class T_1 to 187.76 'F', 124.28 'D' Kg/tree and 147.21 'F', 104.25 'D' Kg/tree in diameter class T_7 respectively. The proportion of biomass of trunk to whole tree biomass ranged between 65-67% while in case of branch wood and leaves/twigs 17-18% and 13-14% respectively. Fresh biomass of leaves, branch and trunk varied from 2.73, 1.08 and 8.96 (T_1) to 147.21, 187.76 and 554.59 Kg/tree (T_7) respectively while dry biomass ranged from 1.94, 0.71 and 7.37 Kg/tree (T_1) to 104.25, 124.28 and 456.49 Kg/tree respectively for leaves, branch and trunk. It showing increase in diameter there was an increase in fresh leaf, branch and trunk biomass. Total fresh and dry biomass was found to be maximum (889.56 and 685.02 Kg/tree) in T_7 followed by T_6 and T_5 while T_1 recorded minimum values of 12.77 and 10.02 Kg/ tree.

Biomass partitioning varied considerably in different components of the tree. Generally, trunk fraction accounts bulk of the total biomass. Osman *et al.,* (1992) [6] reported that 72-76 percent is allocated to stem and 9-12 percent to leaves in four year old *Acacia auriculiformis* plantation. Tsai (1986) [10] also reported in *A. mangium* plantation that the leaf contributes between 1.9 to 10.6%; branch wood between 8.0 to 39% and stem between 55.6 to 87.9% while in open grown tree stem portion account for less than 47%, leaf contributes between 13.8-22.7% and branches between 34.1-49.5% of the total biomass.

The relationship between DBH (x) and dry biomass of leaves (Y) was positive with R^2 value of 0.766. The linear equation developed is $Y= 5.0971x - 18.485$. (Fig. 3.1)

The linear relationship between DBH (x) and dry biomass of branch wood (Y) was positive (R^2 value is 0.756 and linear equation is $Y=6.5911x - 22.604$). (Fig. 3.1)

The linear relationship between DBH and dry biomass of tree trunk was positive with R^2 value of 0.911 and linear equation is $Y=25.041x – 72.627$, where Y = dry tree trunk biomass and 'x' is DBH. (Fig. 3.1)

The relationship was strong and positive between DBH and dry biomass of whole tree (R^2 value is 0.891 and linear equation (Y) = 36.729x -113.72). (Fig. 3.1)

Table 3.1: Above ground fresh biomass of different parts of trees across different diameter classes in *Acacia mangium*

Treatments	Leaves biomass (Kg/tree)	Branch wood biomass (Kg/tree)	Tree trunk biomass (Kg/tree)	Total tree biomass (Kg/tree)
T_1: < 5 cm Dia.	2.73	1.08	8.96	12.77
T_2: 5-10 cm Dia.	10.26	9.93	39	59.19
T_3: 10-15 cm Dia.	21.6	38.01	152.15	211.76
T_4: 15-20 cm Dia.	38.69	67.68	186.42	292.79
T_5: 20-25 cm Dia.	66.91	89.93	344.7	501.54
T_6: 25-30 cm Dia.	84.08	133.3	439.09	656.47
T_7: 30-35 cm Dia.	147.21	187.76	554.59	889.56
C.V. (%)	36.91	48.39	15.87	21.57
SEm (±)	11.31	21.06	22.58	46.68
C.D. @ 5%	34.3	63.88	68.49	141.6

Table 3.2: Above ground dry biomass of different parts of trees across different diameter classes in *Acacia mangium*

Treatments	Leaves biomass (Kg/tree)	Branch wood biomass (Kg/tree)	Tree trunk biomass (Kg/tree)	Total tree biomass (Kg/tree)
T_1: < 5 cm Dia.	1.94	0.71	7.37	10.02
T_2: 5-10 cm Dia.	7.26	6.57	32.1	45.94
T_3: 10-15 cm Dia.	15.29	25.16	125.24	165.69
T_4: 15-20 cm Dia.	27.4	44.8	153.41	225.61
T_5: 20-25 cm Dia.	47.39	59.53	283.72	390.64
T_6: 25-30 cm Dia.	59.55	88.23	361.41	509.19
T_7: 30-35 cm Dia.	104.25	124.28	456.49	685.02
C.V. (%)	36.92	48.39	15.87	20.69
SEm (±)	8.01	13.94	18.59	34.67
C.D. @ 5%	24.29	42.28	56.38	105.17

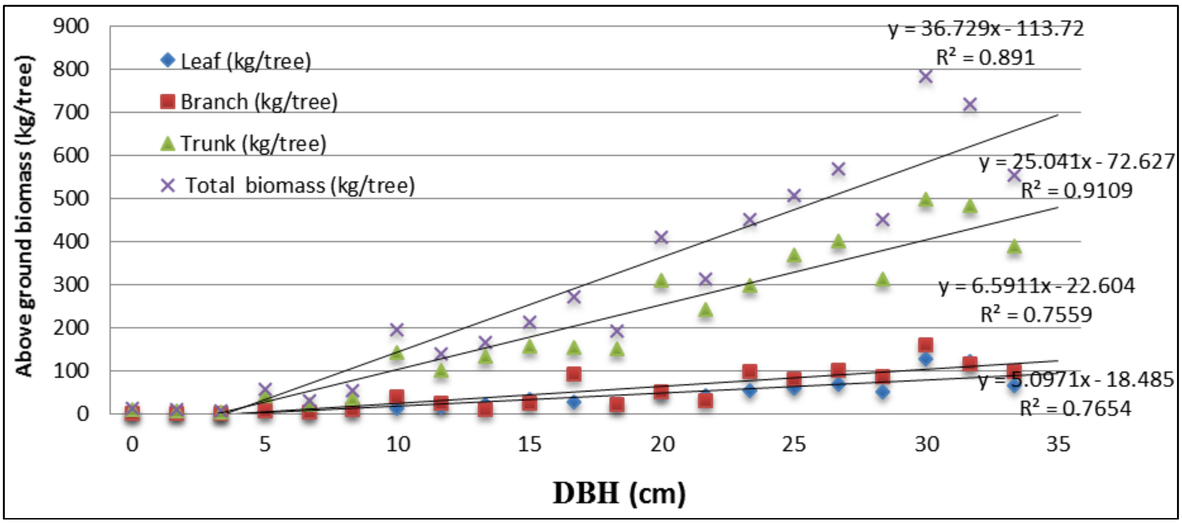

Fig 3.1: Relationship of DBH with dry biomass of leaf, branch, trunk and total (above ground) dry biomass in Acaica mangium

3.3 Below ground fresh and dry biomass

Roots are difficult to extract and are rarely measured though destructive method. The tree had well developed tap root (Primary root) system but differed in the relative abundance in lateral roots (secondary roots) and root depth. Roots in number and mass of tree were concentrated in top one meter of soil profile spreading parallel to the ground and some penetrating vertically. One meter cubic portion of root skeleton is uprooted and weighed. The result showed that root biomass was positive correlated (R^2= 0.740) with DBH, total root biomass increase with increase in diameter classes from T_1 (< 5 cm) to T_7 (30–35 cm). similar result was recorded by Caldeira *et al.*, (2011) in *Acacia mearnsii.* The result shown maximum fresh and dry root biomass (202.52, 125.00 Kg/tree) in T_7 because of presence of big size trees in T_7 diameter class. The data on below ground biomass of primary and secondary roots of *Acacia mangium* of different diameter classes are presented in table 3.3 and the same graphically presented in Fig. 3.2.

3.3.1 Fresh and dry biomass of primary roots

Analysis of variation indicated that maximum fresh weight of primary root was found in T_7 (162.40 Kg/tree), followed by T_6 (128.11 Kg/tree) and T_5 (104.61 Kg/tree). This was minimum in T_1 (1.17 Kg/tree) and T_2 (15.26 Kg/tree).

The maximum dry weight (101.83 Kg/tree) of primary roots was found in T_7 and it was statistically at par with T_6 (78.13 Kg/tree) while minimum (0.64 Kg/tree) was in T_1 and that was statistically at par with T_2 (8.07 Kg/tree), T_3 (20.82 Kg/tree) and T_4 (28.59 Kg/tree). The linear regression between DBH and dry biomass of primary roots was positive with R^2 value of 0.729 and linear equation developed was Y= 5.467x -17.534. (Fig. 3.2)

3.3.2 Fresh and dry biomass of secondary roots (Kg/tree)

Both fresh and dry weight of secondary roots showed significant variation among different diameter classes. The maximum fresh weight of secondary roots of 40.13 Kg/tree was recorded in T_7 which is at par with T_6 (34.38 Kg/tree) and T_5 (26.01 Kg/tree). As usual, T_1 and T_2 recorded the least biomass of secondary roots (0.38 and 1.99 Kg/tree, respectively).

The maximum dry weight of secondary roots was 23.18 Kg/tree recorded in T_7, followed by T_6 (18.87 Kg/tree), whereas T_1 and T_2 recorded the minimum values of 0.18 and 0.94 Kg/tree, respectively. The linear association was positive between DBH and dry biomass of secondary roots (R^2 = 0.728). (Fig. 3.2)

3.3.3 Fresh and dry biomass of total roots (Kg/tree)

Biomass of total roots refers to biomass of primary and secondary roots. Below ground fresh biomass of roots was found maximum in T_7 (202.52 Kg/tree) and it was statistically at par with T_6 (162.49 Kg/tree) and T_5 (130.63 Kg/tree). T_1 recorded minimum fresh root biomass (1.55 Kg/tree), followed by T_2 (17.25 Kg/tree), T_3 (49.05 Kg/tree) and T_4 (61.75).

Below ground dry biomass of roots was found to be maximum in T_7 (125.00 Kg/tree), followed by T_6 (97.00 Kg/tree). In contrast, trees with lower diameter classes were recorded the least biomass of root. For instance, T_1 recorded 0.82 Kg/tree, T_2 recorded 9.00 kg/tree and T_3 recorded 26.00 kg/tree root biomass. Moreover, total root biomass was positively associated with DBH representing R^2 value of 0.741 and the linear equation of Y=6.7675x – 22.724. (Fig. 3.2)

3.3.4 Total Dry biomass of roots (ton/ha)

Maximum Total Dry biomass of roots (312.50 ton/ha) was recorded in T_7 which was statistically at par with T_6 (242.50 ton/ha) while minimum in T_1 (2.05 ton/ha) which was statistically at par with T_2 (22.50 ton/ha), T_3 (65.00 ton/ha) and T_4 (80.83 ton/ha).

Table 3.3: Fresh and dry biomass of primary, secondary, total root (Kg/tree) and total dry root biomass (ton/ha) of trees of different diameter classes in *Acacia mangium*

Treatments	Biomass of Primary roots (Kg/ Tree)		Biomass of secondary roots (Kg/ Tree)		Total fresh biomass of root (Kg/tree)	Total dry biomass of root (Kg/tree)	Total dry root biomass** (ton/ha)
	Fresh biomass	Dry biomass	Fresh biomass	Dry biomass			
$T_{1:}$ < 5 cm Dia.	1.17	0.64	0.38	0.18	1.55	0.82	2.05
$T_{2:}$ 5-10 cm Dia.	15.26	8.07	1.99	0.94	17.25	9	22.5
$T_{3:}$ 10-15 cm Dia.	38.11	20.82	10.94	5.18	49.05	26	65
$T_{4:}$ 15-20 cm Dia.	54.03	28.59	7.73	3.75	61.75	32.33	80.83
$T_{5:}$ 20-25 cm Dia.	104.61	58.81	26.01	13.19	130.63	72	180
$T_{6:}$ 25-30 cm Dia.	128.11	78.13	34.38	18.87	162.49	97	242.5
$T_{7:}$ 30-35 cm Dia.	162.4	101.83	40.13	23.18	202.52	125	312.5
C.V. (%)	45.44	48.07	40.88	46.17	42.06	45.71	45.71
SEm (±)	18.88	11.77	4.1	2.49	21.69	13.65	34.13
C.D. @ 5%	57.26	35.7	12.43	7.54	73.17	41.41	103.53

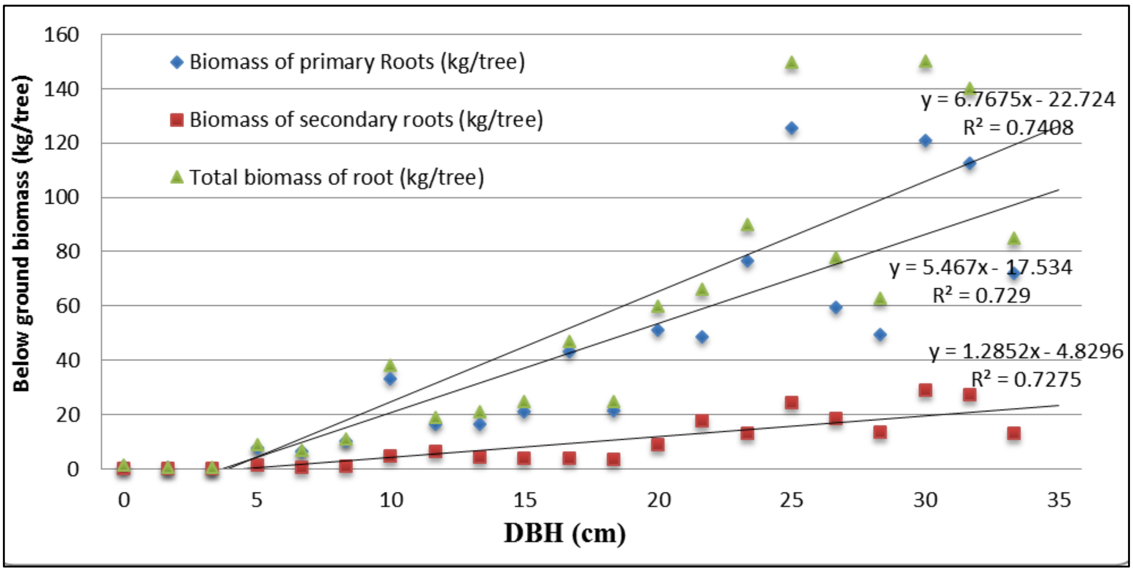

Fig 3.2: Relationship of DBH with dry biomass of primary roots, secondary roots and total root dry biomass in Acaica mangium

3.4 Proportional distribution of above and below ground fresh and dry biomass of *A. mangium*

In the present study, both above and below ground biomass varied from lower diameter classes to higher diameter classes, where maximum total fresh biomass of tree was found to be 1092.09 Kg/tree in T_7, and minimum of 14.32 Kg/tree in T_1 (Table 3.4). Whereas total dry biomass (both above and below ground biomass) varied from 10.84 (T_1) to 810.02 Kg/tree (T_7) indicating biomass of tree increases rapidly from lower to higher diameter classes (Table 3.4).

The proportional distribution of above ground (i.e cumulative biomass of leaves, branch wood, tree trunk biomass) and below ground biomass with total biomass (*i.e.* primary and secondary roots on fresh and dry basis) was analyzed across the different diameter classes of *Acacia mangium*. Details of results are tabulated in Table 3.4 and Fig. 3.2The proportional distribution of above ground biomass (on fresh weight basis)

to the total fresh biomass of trees varied from T_1 to T_7 and their proportions are as follows: 89.18%, 77.43%, 81.19%, 82.58%, 79.34%, 80.16% and 81.46%. In the case of proportion of below ground biomass to total biomass (on fresh weight basis), values ranged from 10.82 to 22.57 per cent. Treatment wise proportion of above ground biomass to total biomass and below ground biomass to total biomass is described in Fig. 3.2.
Biomass on the basis of dry weight, the proportional distribution of above ground biomass to the total dry biomass of tree varied among diameter classes and the proportion was 92.44, 83.62, 86.44, 87.47, 84.44, 84.00 and 84.57 percent respectively from T_1 to T_7. Similarly, proportional distribution below ground biomass to the total dry biomass of tree was 7.56, 16.38, 13.56, 12.53, 15.56, 16.00 and 15.43, respectively. Vidyasagaran *et al.*, (2014) [11], Suryawanshi *et al.*, (2014) [8], Devi *et al.*, (2013) [3] and Sundarapandian *et al.*, (2013) [7] also reported similar results of fresh and dry biomass in different studies in other tree species.

Table 3.4: Total fresh and dry biomass of tree in different diameter classes of *Acacia mangium*

Treatments	Total fresh biomass (Kg/tree)	Total dry biomass (Kg/tree)
$T_{1:}$ < 5 cm Dia.	14.32	10.84
$T_{2:}$ 5-10 cm Dia.	76.44	54.94
$T_{3:}$ 10-15 cm Dia.	260.81	191.69
$T_{4:}$ 15-20 cm Dia.	354.5	257.94
$T_{5:}$ 20-25 cm Dia.	632.17	462.64
$T_{6:}$ 25-30 cm Dia.	818.96	606.19
$T_{7:}$ 30-35 cm Dia.	1092.09	810.02
C.V. (%)	23.18	22.4
SEm (±)	62.14	44.23
C.D. @ 5%	188.47	134.17

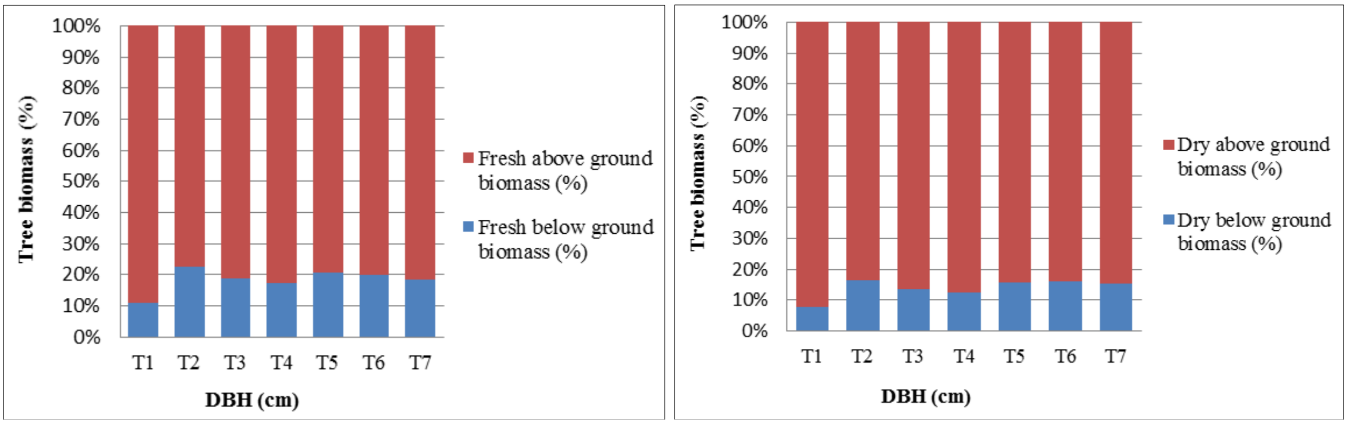

Fig 3.2: Proportion of above and below ground fresh and dry biomass to total tree fresh and dry biomass (%) across different diameter classes in *Acacia mangium*

Conclusion
Present study revealed that among different diameter classes, class T_7 produce higher biomass while class T_1 lowest, because of aboveground biomass of *Acacia mangium* were subjected to diameter at breast height (Dbh) and tree height. The high variability in the DBH, height and biomass of the trees of the same species, origin, age and growing conditions suggest that the variability may be genetic in nature. Aboveground biomass of *A. mangium* plantation showed a very significant relation with diameter at breast height (DBH).

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