Root pattern of some tree species in semi-arid area

KITUI - KENYA

SOFEM

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Preface

The rapidly increasing population in the country and the diminishing land productivity and availability of wood products have reached alarming proportions. This situation is even more critical in the dry areas where growth of both trees and agricultural crops are competing for the scarce soil moisture and plant nutrients.

The application of agroforestry farming system as a way out of the constraint has been promoted in these dry areas as well as elsewhere. In most situations, the trees utilized are those that are drought resistant and thus can tolerate the ASALs. In majority of the cases, the identified tree species are those whose growth performance is high. Unfortunately the management of these trees in an intercropping system has been through trial and error in as far the different spacing between the trees themselves and between trees and the agricultural crops.

Social forestry can be defined as a policy concept that governs tree growing by the people within their individual farms mainly for their own consumption. It includes such practices as establishing nurseries, woodlots within homesteads, boundary and avenue planting mainly to meet their various needs, domestic as well as income generation. The social forestry extension model development project (SOFEM) was initiated in 1997 with the aim of equipping the inhabitants of the ASALs in Kenya with appropriate techniques to plant and also manage trees on their farms. These techniques however are not readily available for adoption and especially in the area of tree-crop interplanting.

This study that was initiated before the SOFEM projects aimed at filling this gap through understanding detailed studies of the growth pattern of 21 indigenous and 18 exotic tree species. An in-depth evaluation of the growth rate of both the shoots and roots, the extent of spread of the roots and the concentration of the root system in different soil horizons allows the classification of suitability of the various species. It is noteworthy to point out that most agricultural crops obtain their nutrients and moisture requirements from within the top 40cm. As result, any tree species that have little of its rot system within this depth and generally have least root spread will allow close spacing while offering least competition to the crops.

It is expected that the results given in this paper will be useful to the many players in agroforestry development in the arid and semi-arid lands of Kitui in particular where the study was done, and Kenya in general.

I would like to thank the many KEFRI and JICA scientific staff members who over a long period of time pursued this study. Further I would like to appreciate the difficult and tedious manual work carried out by the many social forestry training project and later social forestry extension model development project staff members. Their meticulous excavating of the soil to expose the fine roots, the report could not have been what it is without the elaborate and clear illustrations prepared by the Japanese project staff members. To all the persons who made this study a success, I am very grateful.

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While the number of researchers on forestry is not small, reports of study on root system of trees are few. That is true for not only tropical semi-arid species, but for other species in other climatic zones. It is probably due to the difficulty in digging the soil and observing the root system, especially that of trees which develop deep into soil. However, it does not mean that the research on root system of tree species in the semi-arid area is less important. On the contrary, because of the high competition among the trees and grasses in obtaining small amount of water available in the semi-arid area, research on root system is inevitable to know the different strategies of trees to survive on a harsh condition, and apply that knowledge to the activities of establishment of forest and development of agro-forestry systems.

SOFEM (former SFTP) project has been studying on root system of trees since 1993 up to 1999 and obtained information on 39 important tree species in semi-arid area. In our project, during the tree planting activities, we observed very strong competition among the trees planted and other vegetation. In 1992, because of the severe drought, high percentage of trees which had been planted died, and since then we started introducing complete weeding method to minimize competition for water. At the same time, we recognized the importance of research on root system.

Now, nine years after the start of the research, we would like to present the report on the results to people who need the information for research and actual tree planting practice. Some of the results may help to select appropriate trees to plant at appropriate site and develop different tending systems for establishing trees in semi-arid areas. I hope the report also helps to choose proper species for agro-forestry. It is sometimes said that because of the high competition of obtaining water between trees and agricultural crops, it is very difficult to establish agro-forestry systems in semi-arid area. Knowing more of different characters of root system of various species will probably help to create better combination of tree and agricultural species. In fact, some research findings such as the rather fast growth of root system downwards especially that of some indigenous acacia species suggests possibility of developing good agro-forestry systems. Research results may also help to determine the period of intensive tending of trees after planting. Right now, our project needs to solve the issue of how many years we should continue complete weeding after trees are planted.

Since the start of SOFEM project in 1997, our project is addressing more on extension. Advise to farmers based on scientific facts is convincing and necessary. We hope this report will also be utilized by extensionists to know more about different tree species from a new aspect and help their activities in the field with farmers.

Finally, I would like to express my gratitude to those engaged in the study of root system for a long time. Especially, without the assistance of those team members who excavated and measured roots, we could not have completed the work. Also, I would like to express special thanks to those Japanese ladies who illustrated the root system patiently in the field.

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Muneo Segawa
Chief Advisor of the Project

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The root pattern was illustrated by four Japanese;
Mio Kitagawa, Naomi Yamamoto, Yuko Takeuchi and Hidemi Saito

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A. Indigenous species

1) *Acacia gerrardii*
2) *A. mellifera*
3) *A. nilotica*
4) *A. polyacantha*
5) *A. senegal*
6) *A. sieberiana*
7) *A.tortillis*
8) *Albizia anthelmintica*
9) *Balanites aegyptiaca*
10) *Berchemia discolor*
11) *Coridia ovalis*
12) *Croton megalocarpus*
13) *Dalbergia melanoxylon*
14) *Faidherbia albida*
15) *Grewia aricantha*
16) *Melia volkensii*
17) *Tamarindus indica*
18) *Terminalia brownii*
19) *T. prunioides*
20) *Vitex doniana*
21) *Ziziphus mauritiana*

B. Exiotic species

1) *Acacia auriculiformis*
2) *A. holosericea*
3) *Albizia lebbeck*
4) *Azadirachta indica*
5) *Carica papaya*
6) *Casuarina equisetifolia*
7) *Dovyalis caffra*
8) *Eucaliptus paniculata*
9) *Grevillea robusta*
10) *Jacaranda mimosifolia*
11) *Leucaena leucocephala*
12) *Moringa oleifera*
13) *Percea americana*
14) *Prosopis juliflora*
15) *Psidium guajava*
16) *Senna siamea*
17) *S. spectabilis*
18) *Terminalia mentalis*

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1. INTRODUCTION

The type of root system developed by a plant species (taproot or fibrous root system) is genetically pre-determined. In addition, root proliferation has been correlated with nutrient and water deficiencies in soils while soil compaction poses resistance that limit full expression of genetic potentials by plants.

In semi-arid area where the soil moisture deficit is a critical factor in plant establishment, one of the main factors which affects the survival and growth of plants is its ability of exploiting moisture from deeper horizons. In other words, plant growth and survival under drier condition depend on how its rooting system exploits different horizons for both water and nutrients. Therefore it is important to understand the rooting pattern of each tree species and its ability to endure the severe condition in semi-arid area.

The root system development survey started 1993 during the period of Social Forestry Training Project (SFTP) phase II. It was taken over by the Social Forestry Extension Model Development Project (SOFEM) up to 1999. During this period, 39 important tree species (21 indigenous and 18 exotic) in semi-arid area were selected, planted and their root systems analyzed. This is to report the outcome of these activities.

2. OBJECTIVE

The objective was to study the characteristics of the root pattern of different tree species and the relationship to survival and growth in the semi-arid area.

3. SITE DESCRIPTION

A) Site

TIVA Pilot Forest, Yatta Division, Kitui District

B) Climate

Average annual rainfall is 700mm, Agro-climatic zone is V-1.

C) Soil

The soil type is Acrisols. There is a marrum layer appearing from 50cm below, or sometimes 300cm below, which is a weathered layer from basement rock and is hard and with poor moisture retention capacity.

4. METHOD OF SURVEY

4-1) Target species and number of trees

A total of 687 trees of 39 species were studied since the year 1993 (Table 1). Each experiment had 4 replicates and each replicate had 10 trees per species, so 40 trees were planted per species. Planting was done in November of each year.

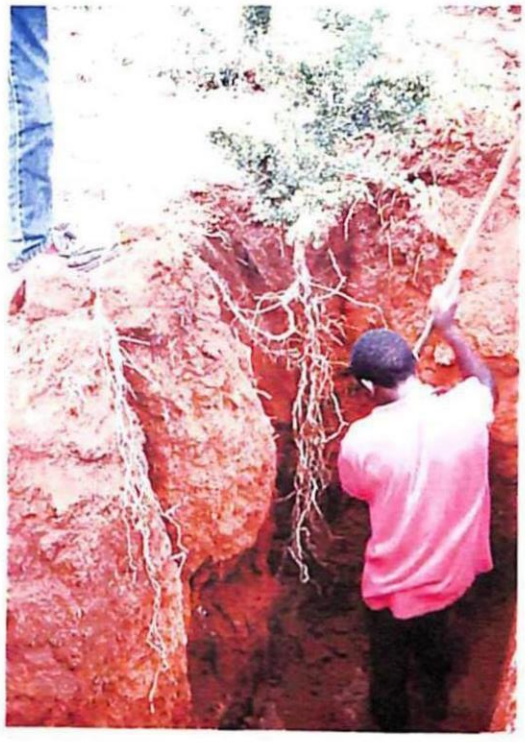
Extraction was done at six months and one and a half-years after planting. One to two trees per replicate, which meant four to eight trees per species, were selected six months after planting for the survey. After one year and a half, one tree per replicate was again selected for the survey.

4-2) Survey methods and parameters

The excavation was done by an excavator positioned at a distance from the base of the tree. Then, the soil was removed carefully from both sides to expose the roots by use of jembes, crow bars and hands (Fig. 1 and 2).

Number of visible roots and their depths were recorded, where possible without detaching its roots. The extent of horizontal root spread was determined by marking all the lateral roots across the soil profile. Vertical roots were mapped by tracing the main roots down the profiles. After the completion of the mapping, root collar was measured and roots and stems separated. Root densities were recorded at different soil profiles (0-20, 20-50, 50-75 and beyond 75cm). Fresh and dry weights were taken for both the shoots and the roots. Parameters taken include; shoot length, whole root length, root width, main root/small root numbers (density) which were taken at different root levels, shoot weight and root weight.

(Fig.1) Excavation



(Fig.2) Removing soil

As it is very difficult to draw the root pattern as it actually grows, it must be noted that the recorded length and width measured are sometimes shorter than its actual one. It is also difficult to excavate roots completely including small roots as small roots are easily cut and removed with soil. Therefore, the number of roots counted may be less than the actual number. However, the root weight may be more reliable since the loss of small roots does not affect the weight much.

(Table 1) **Target species and number of surveyed trees**

Planted	Surveyed Species	1994 Mar	1994 Jul	1994 Oct	1995 Mar	1995 Jul	1996 Apr	1997 May	1998 Jun	1999 Jun
1993	*A.nilotica*	8	8	8	7					
	A.polyacantha	8	8	8	8					
	B.aegyptiaca	8	8	8	7					
	C.megalocarpus	8	8	8	7					
	D.melanoxylon	8	8	8	8					
	M.volkensii	8	8	8	8					
	P.juliflora	8	8	8	8					
	S.siamea	8	8	8	8					
	S.spectabilis	8	6	5	6					
	T.indica	8	8	8	8					
		80	78	75	75					
1994	*A.indica*				8	4	4			
	A.gerrardii				8	4	4			
	A.mellifera				8	4	4			
	A.nilotica				8	4	4			
	C.equisetifolia				8	4	4			
	D.melanoxylon				8	4	4			
	M.volkensii				8	4	4			
	P.juliflora				8	4	4			
	S.siamea				8	4	4			
	T.brownii				8	4	4			
					80	40	40			
1995	*A.holosericea*						8	4		
	A.senegal						8	4		
	A.tortolis						8	4		
	A.anthelmintica						8	4		
	C. ovalis						8	4		
	E.paniculata						8	4		
	F.albida						8	4		
	G.robusta						8	4		
	J.mimosifolia						8	4		
	L.leucocephala						8	4		
							80	40		
1996	*A. lebbeck*							8	4	
	B. discolor							7	3	
	D. caffra							5	3	
	M. oleifera							4	3	
	T. mentalis							8	3	
	T. prunioides							5	2	
								37	18	
1997	*A.auriculliformis*								5	2
	A.sieberiana								3	2
	C. papaya								2	1
	G.aricantha								4	1
	P. americana								4	2
	P. guajava								4	2
	V.doniana								4	2
	Z.mauritiana								4	2
									30	14

5. RESULTS AND DISCUSSION

The average value of each species, after a half year and one and a half year, are attached (appendix 1).

5-1) Root length and width

The species studied can be divided into 4 groups according to the root length and width. Root width 200cm after one and a half-year is considered because trees are planted at 4m spacing. The species whose root width is over 200cm seems that competition for water occurs after 1 and a half-year. (Fig. 3 and 4). Referring to the growth after one and a half years (Fig.4), the trees can be grouped as follows.

Group 1: Slow growing root system group(length<200cm, width<200cm)

Among the exotic species, *Moringa oleifera, Azadirachta indica, Persea americana* and *Casuarina equisetifolia* are classified as slow growing group. *Moringa oleifera* has the least root growth among the exotic species.

Among the indeginious species, *Berchemia discolor, Balanites aegyptiaca, Dalbergia melanoxylon, Croton megalocarpus* and *Vitex doniana* are categorized as slow growing.

Group 2: Deep but narrow root system group (length>200cm, width<200cm)

Among the exotic species, only *Dovyalis caffra* and *Albizia lebbeck* are fall in deep but narrow group.

Among the indigenous species, many species are classified in this group like *Terminalia prunioides, Acacia sieberiana, Acacia mellifera, Tamarindus indica, Albizia anthelmintica, Acacia senegal* and *Faidherbia albida*. The root of *Faidherbia albida* grows very deep but does not spread widely.

Group3: Shallow and spreading root system group (length<200cm, width>200cm)

Among the exotic species, *Senna spectabilis, Psidium guajava* and *Grevillea robusta* belongs to this group.

Among the indeginous species, only *Melia volkensii* and *Terminalia brownii* are classified in this group.

Group4: Growing both wide and deep root system group (length>200cm, width>200cm)

Among the exotic species, *Prosopis juliflora, Carica papaya, Leucaena leucocephala, Senna siamea, Jacaranda mimosifolia, Acacia holosericea, A. auriculliformis* and *Eucalyptus paniculata* are categolized into this group.

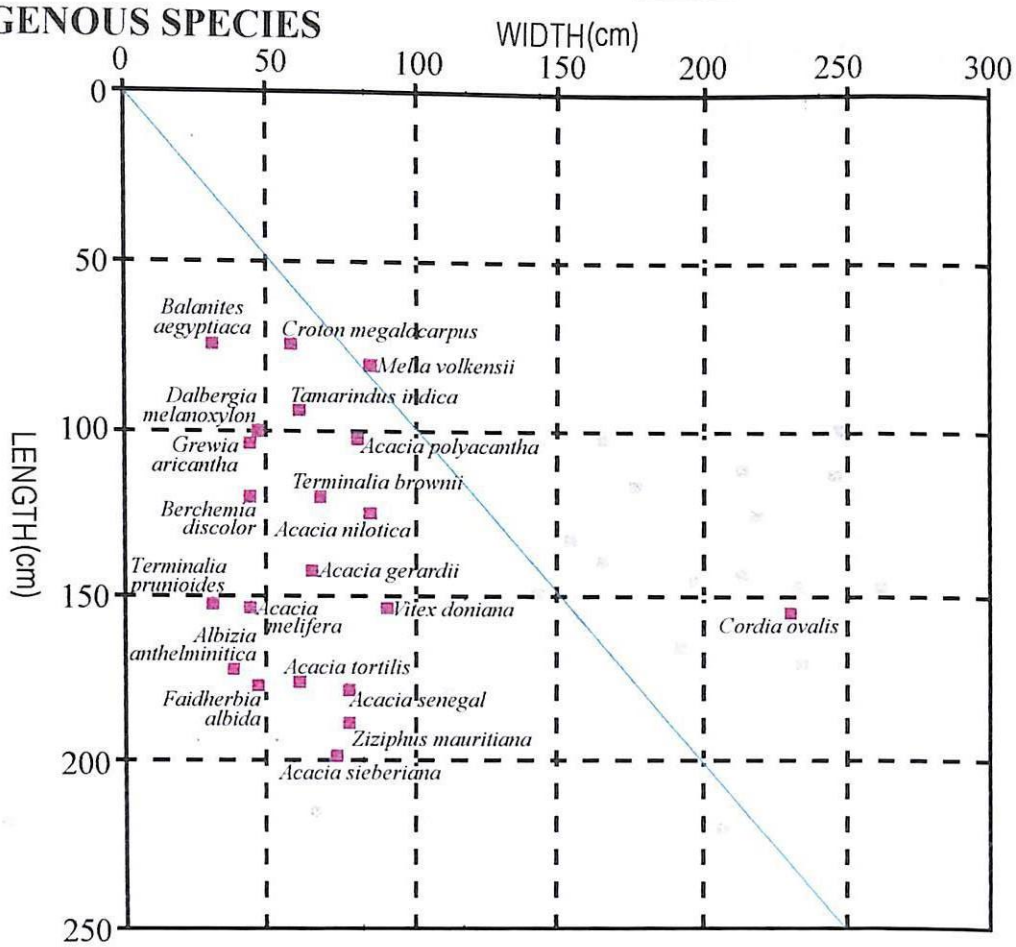
Among the indigenous species, *Acacia nilotica, A. polyacantha, A. gerradii, A. tortilis, Zizyphus mauritiana* and *Cordia ovalis* are classified in this group. The root of *Cordia ovalis* grows very well with a width of 600cm and depth of 330cm in one and a half years.

5-2) Shoot height and root depth (Fig.5-1, 5-2, 5-3, 5-4)

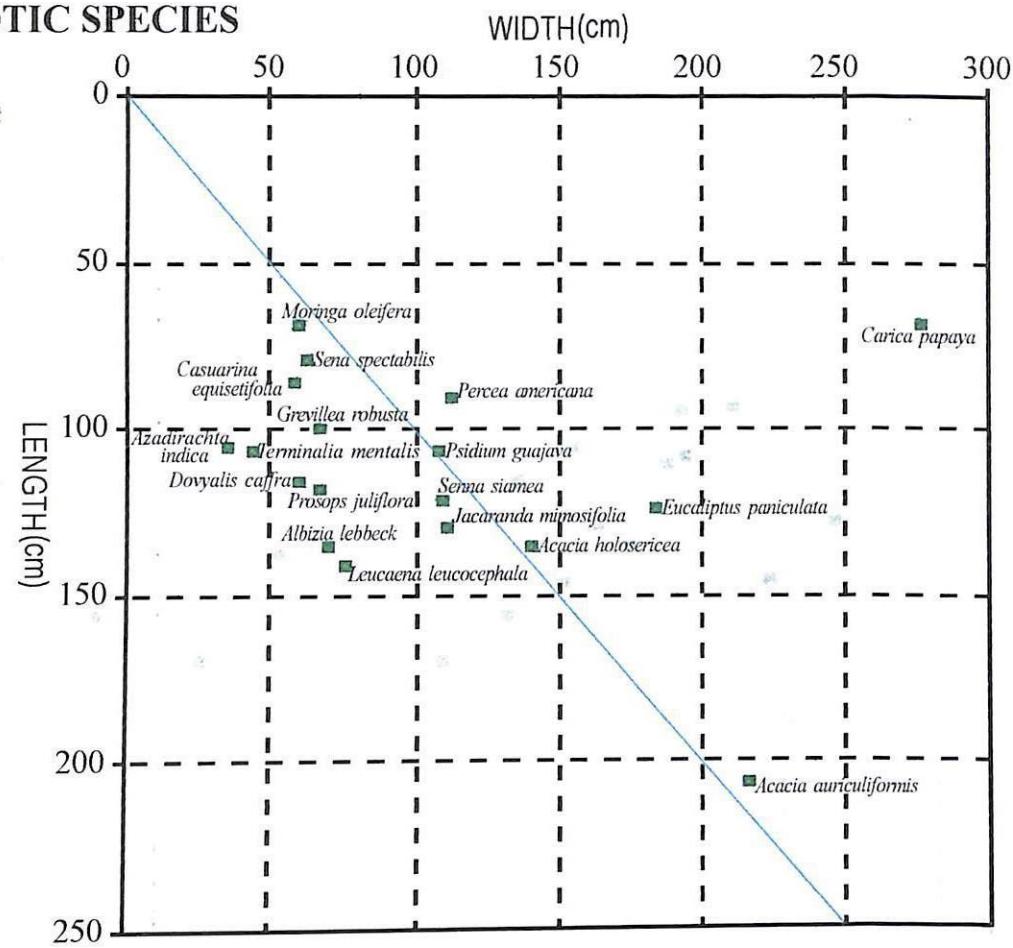
Fig.5-1 to 5-4 show the average shoot length, root length and shoot/root length ratio. In each graph, the more the species is to the left, the higher is root growth than the shoot growth. Generally speaking, it was observed that the shoot/root length ratio of most of the indigenous species is relatively lower than exotic species. It is also observed that the root of both fast and slow growing species grows deep, at least 140cm.

(Fig.3) LENGTH & WIDTH OF ROOT *AFTER 6 MONTHS*

INDIGENOUS SPECIES

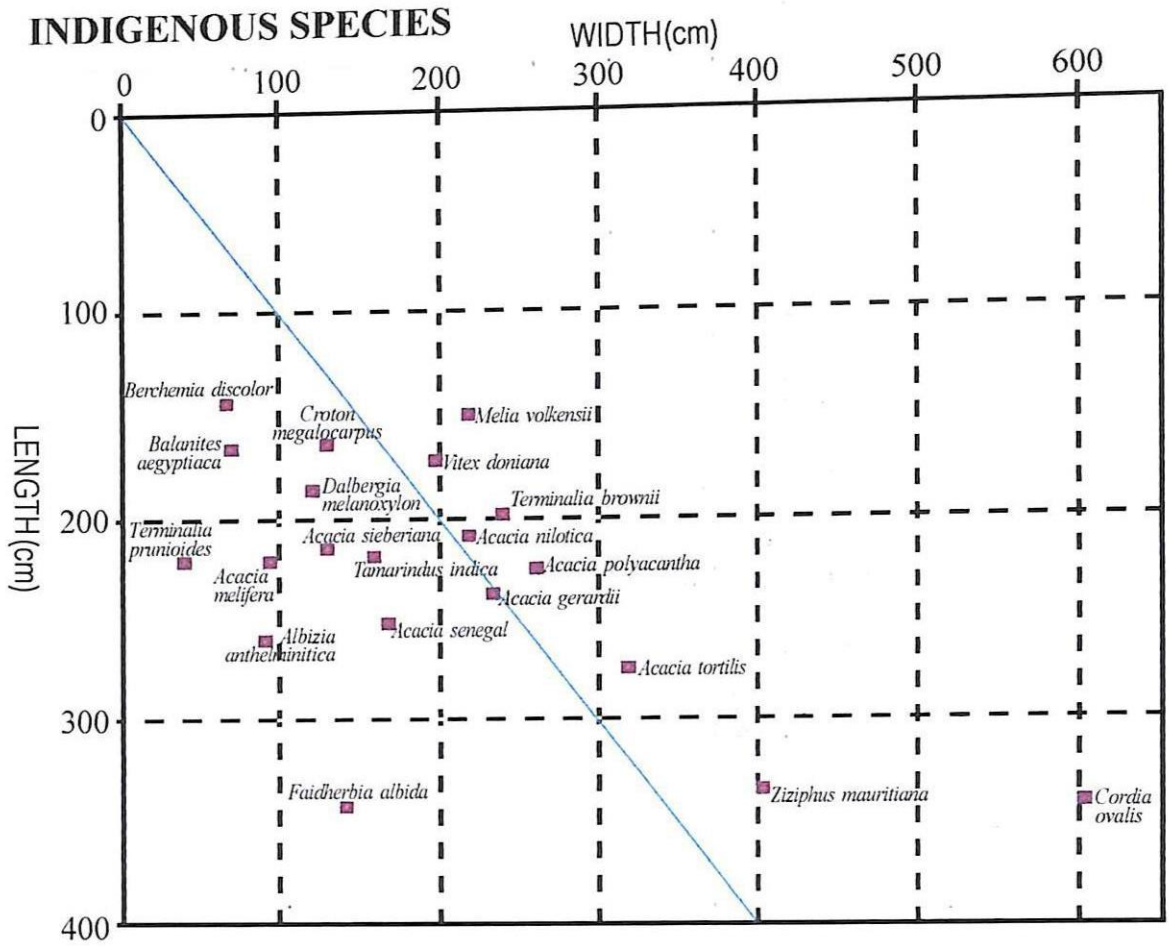


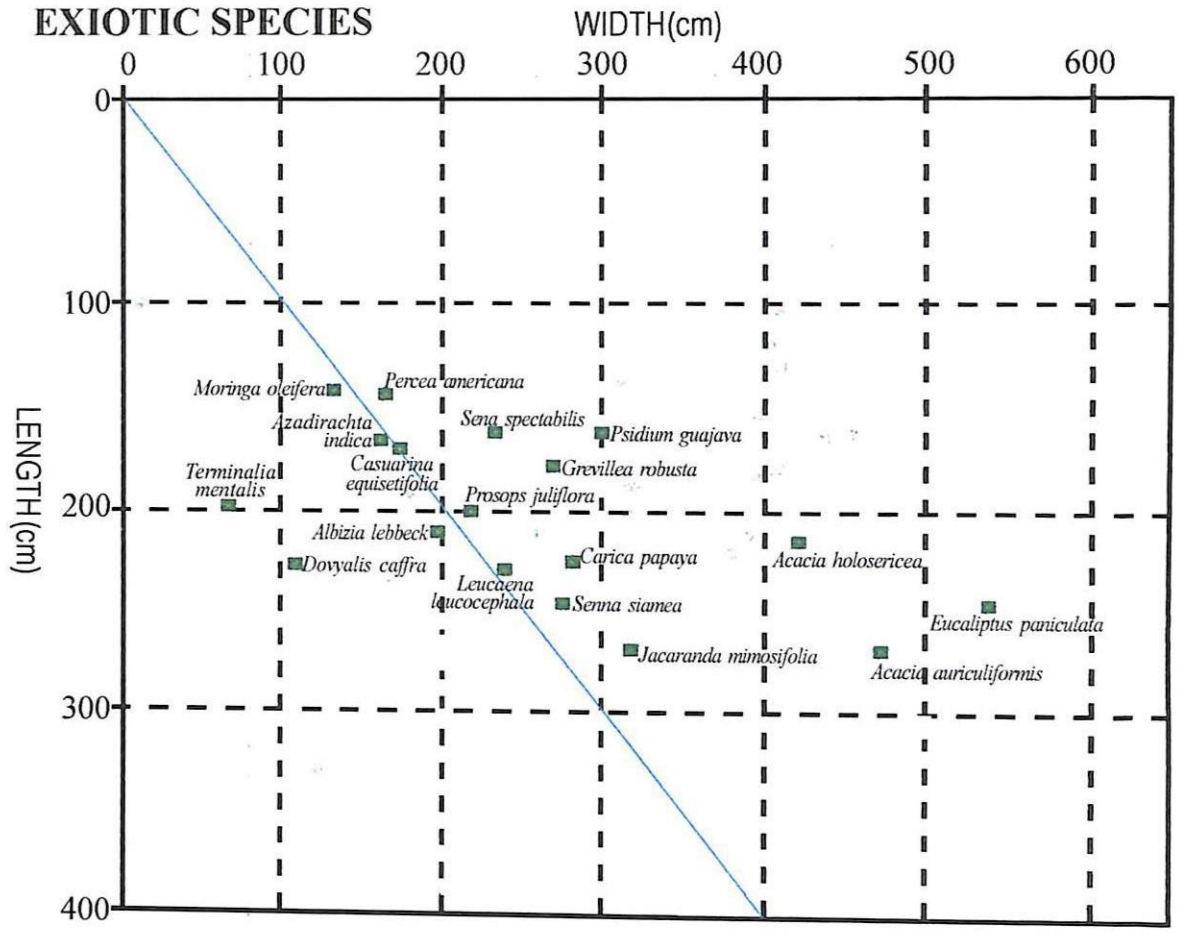
EXIOTIC SPECIES



(Fig.4) LENGTH & WIDTH OF ROOT

AFTER ONE & A HALF YEAR





The shoot of species on the left side of the Fig. 3 and 4 grows slowly, instead, they grow deeper roots to prepare for the dry period. The slow growing species with moderate root growth are; *Terminalia prunioides, Acacia melifera, Albizia anthelmintica, Balanites aegyptiaca, Tamarindus indica, Dalbergia melanoxylon, Acacia gerardii, Vitex doniana, Cordia ovalis* (indigenous species), and *Terminalia mentalis, Dovyalis cafra, Prosopis juliflora* (exotic species).

There are some species whose shoot and root grows fast. These are; *Ziziphus mauritiana, Faidherbia albida* and *Acacia tortilis* (indigenous species) and *Jacaranda mimosifolia, Eucaliptus paniculata, Acacia auriculiformis* and *Acacia holosericea* (exotic species). These species are also considered tolerant to drought.

The shoot/root length ratio of *Melia volkensii* and *Grevillea robusta* is the highest among the indigenous and exotic groups, respectively. Their roots spread out however not deeply, especially that of *Melia volkensii* which is drought tolerant.

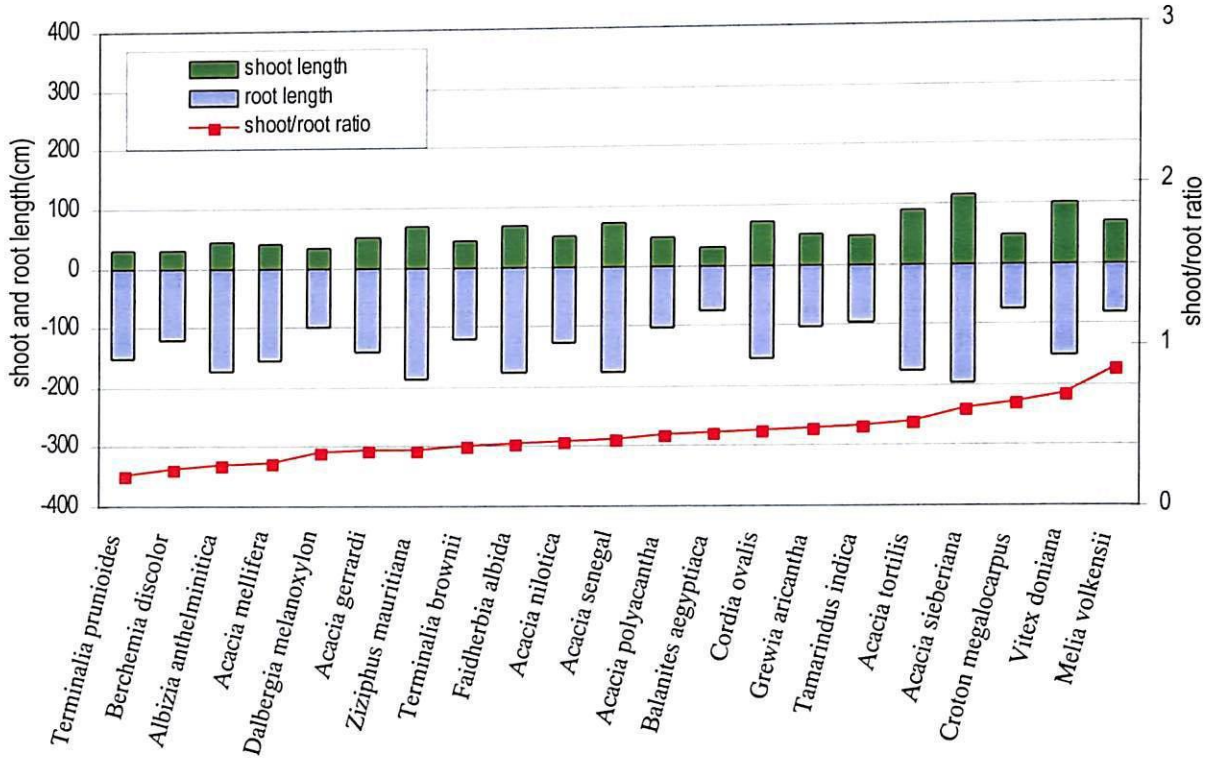
5-3) Shoot and root weight ratio (fresh weight) (Fig.6-1, 6-2, 6-3, 6-4)

The shoot and root weight ratio may relate to the degree of drought tolerance and growth. If the root biomass is larger compared to the shoot, it can take a lot of moisture and nutrient from the soil and can save evaporation through its leaves.

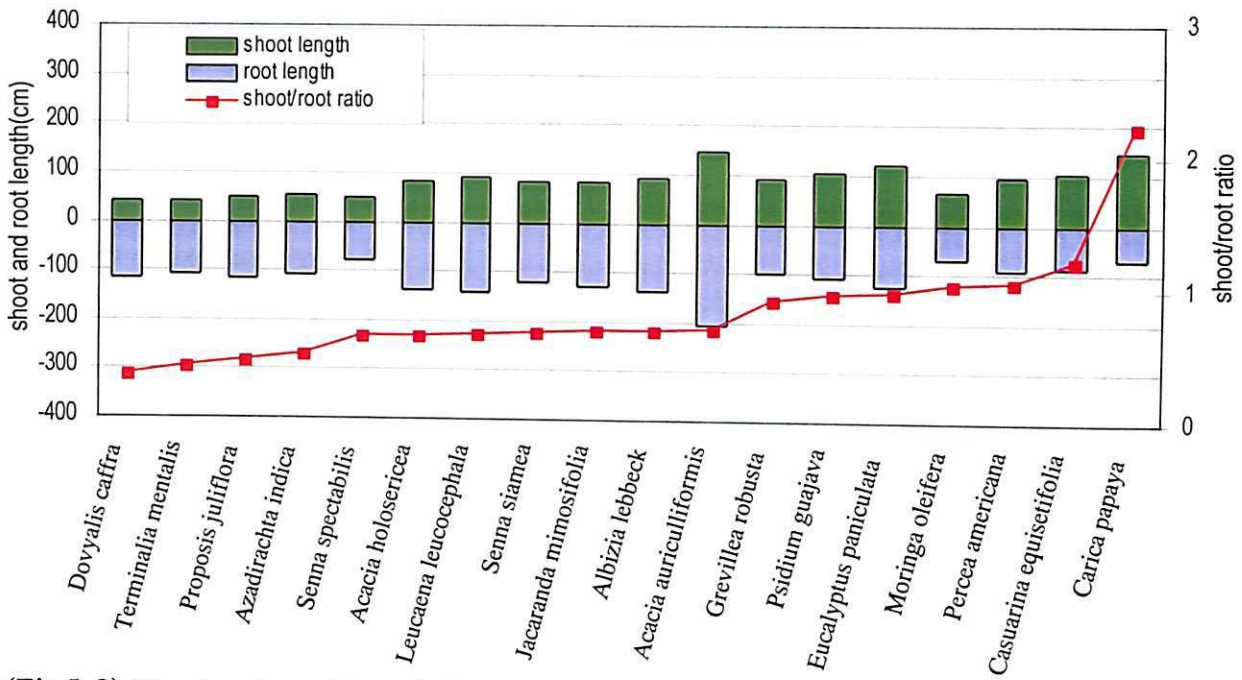
The species which shows lower T/R(shoot and root weight ratio) are; *Berchemia discolor, Albizia anthelmintica, Dalbergia melanoxylon, Terminalia prunioides, Balanites aegyptiaca, Acacia mellifera, Tamarindus indica, Vitex doniana* and *Faidherbia albida* among the indigenous species, and *Moringa oleifera, Albizia lebbeck Dovyalis caffra, Azadirachta indica* and *Jacaranda mimosifolia* as for the exotic species.

After six months both shoot and root biomass of *Carica papaya* is much larger than other species. It grows both shoot and root in its earlier stage to secure moisture. Such a species may therefore require moisture supplement or be planted in terraces.

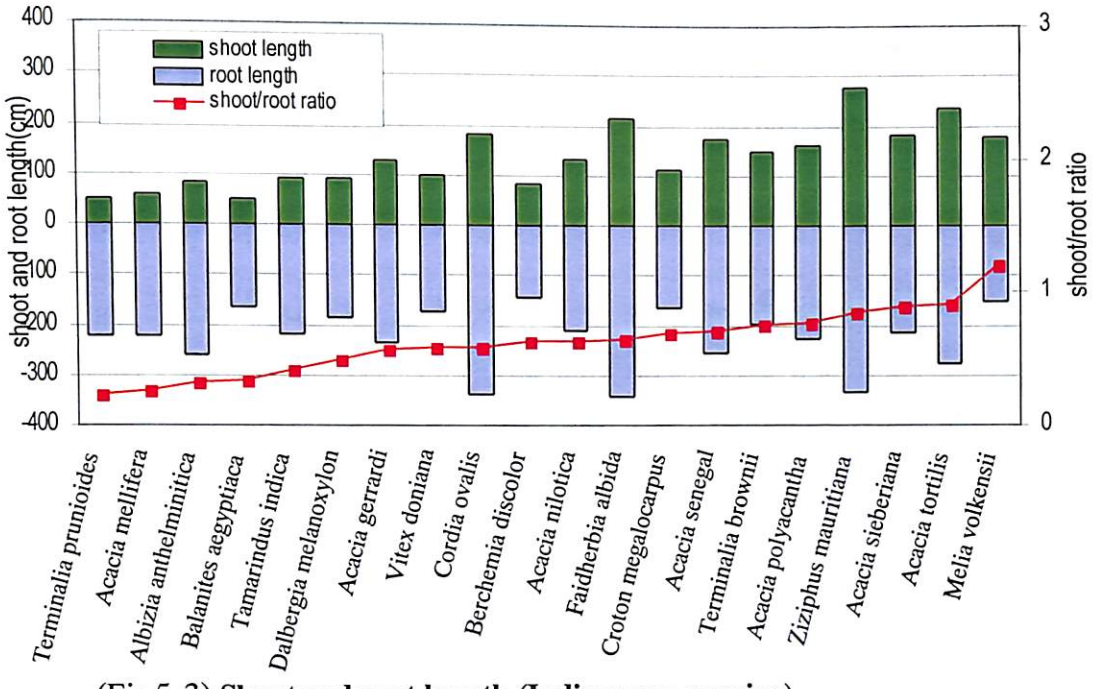
There are some species whose shoot and root biomass are relatively large. These are; *Ziziphus mauritiana* and *Cordia ovalis* (indigenous species), and *Acacia auriculliformis, Eucalyptus paniculata, Grevillea robusta, Jacaranda mimosifolia* and *Acacia holosericea* (exotic species). Such species that have a capacity to put up large biomass within a short time require more moisture and nutrients. They may be more competitive with agricultural crops in both short and long term.



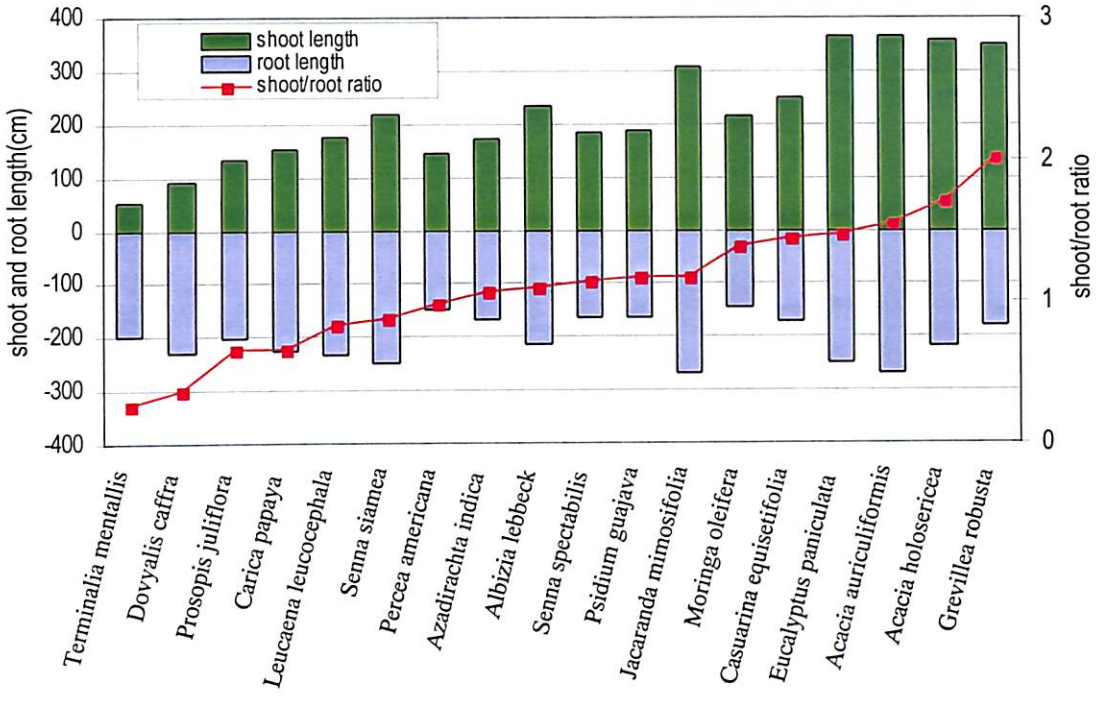
(Fig.5-1) **Soot and root length (Indigenous species)**
(6 months after planted)



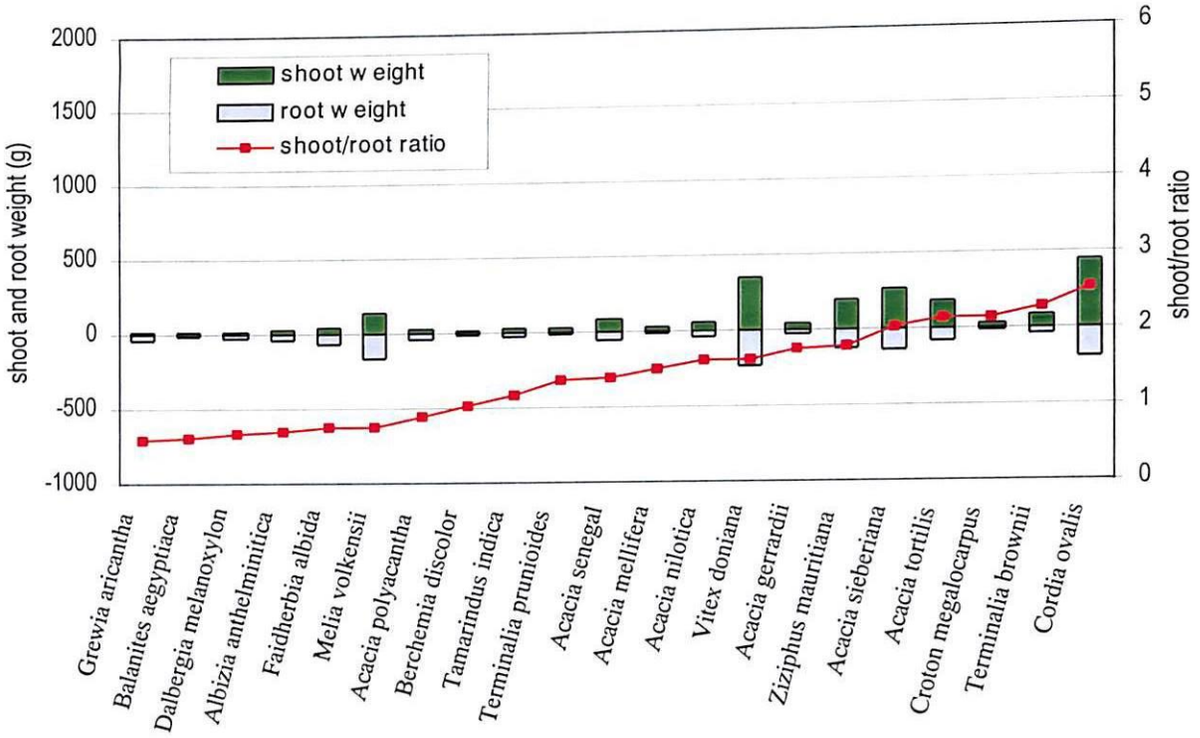
(Fig.5-2) **Shoot and root length (Exotic species)**
(6 month after planted)



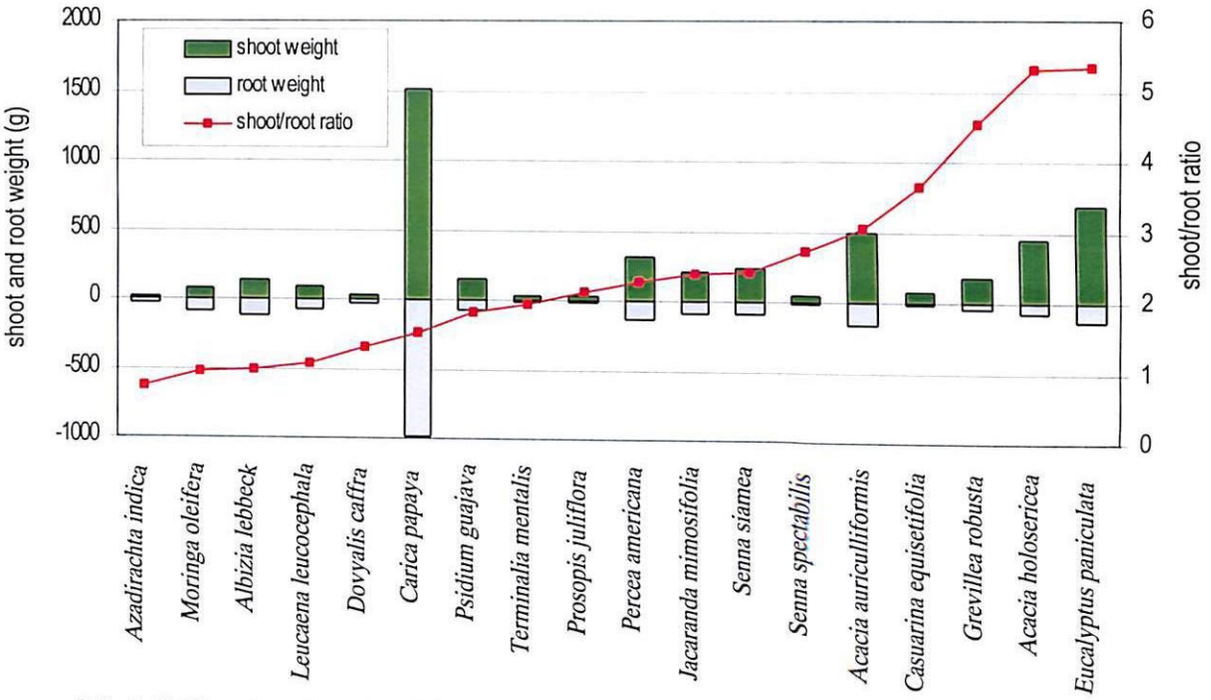
(Fig.5-3) **Shoot and root length (Indigenous species)**
(1 and a half year after planted)



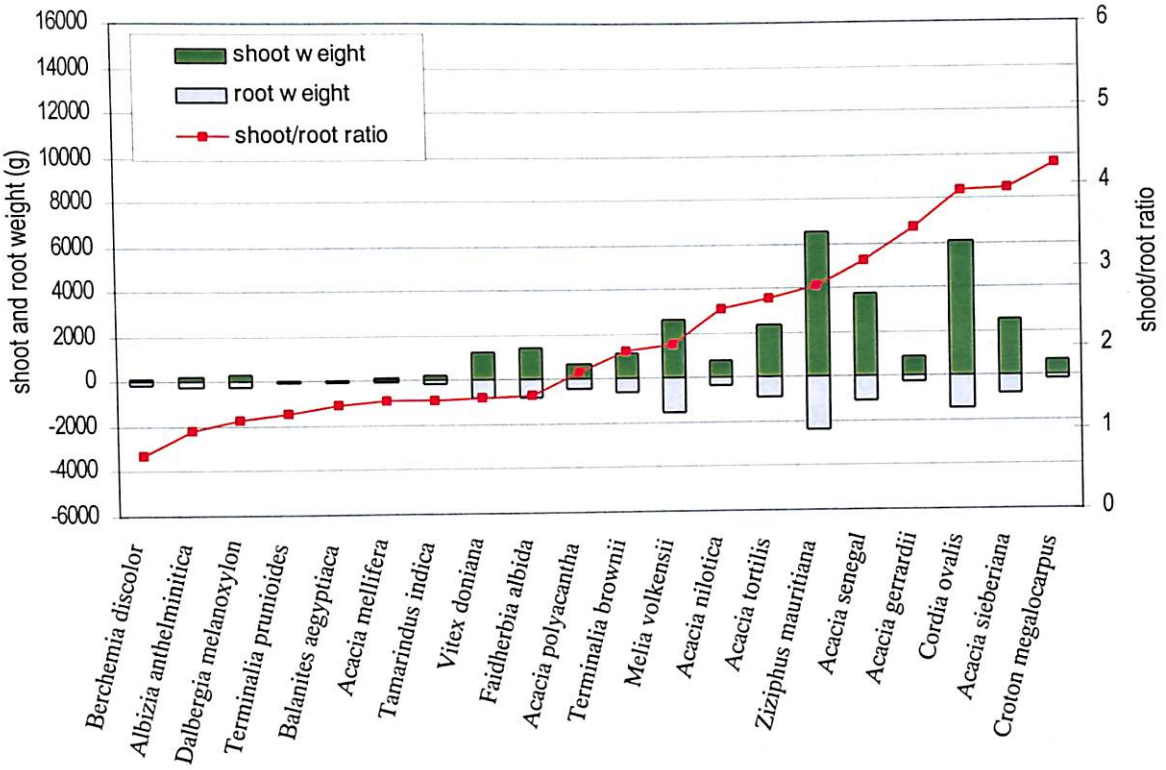
(Fig.5-4) **Shoot and root length (Exotic species)**
(1 and a half year after planted)



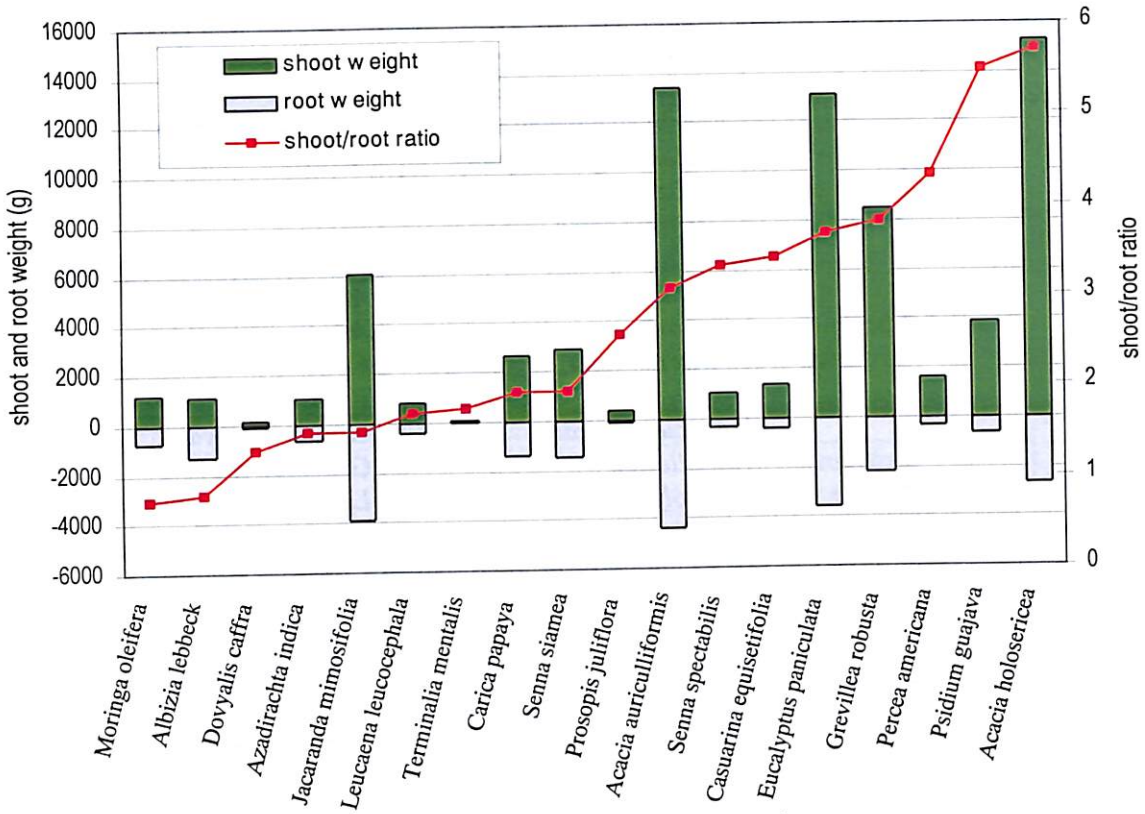
(Fig.6-1) **Shoot and root weight (Indigenous species)**
(6 month after planted)



(Fig.6-2) **Shoot and root weight (Exotic species)**
(6 month after planted)



(Fig.6-3) **Shoot and root weight (Indigenous species)**
(1 and a half year after planted)



(Fig.6-4) **Shoot and root weight (Exotic species)**
(1 and a half year after planted)

5-4) Root width

The maximum root width is one of the main factors by which the spacing of a plant is determined. For example, there are trees whose maximum root width is over 4m after one and a half- year. If they are planted at 3.5m or 4m spacing, competition for moisture may begin in the second year. Such species are; *Cordia ovalis* and *Ziziphus mauritiana* (indigenous species) and *Acacia auriculliformis, A. holosericea* and *Eucalyptus paniculata* (exotic species) (Table 2). When these trees are planted, wider spacing should be considered or mix item with other species whose maximum root width is narrow.

In contrast, there are trees whose maximum root width is under 1.5m after one and a half-year. It can be assumed that competition may not occur for more than 3 years if they are planted at 3.5m or 4m spacing. It will also be suggested that these trees can be planted in a closer spacing than the wide type. Besides, they may not compete for water with crops as fast as those with wider root width. These species are; *Acacia melifera, A. sieberiana, Albizia anthelmintica, Balanites aegyptiaca, Berchemia discolor, Terminalia prunioides, Croton megalocarpus, Dalbergia melanoxylon, Dovyalis caffra* and *Faidherbia albida* (indigenous species), and *Terminalia mentalis* and *Moringa oleifera* (exotic species).

(Table 2) **Maximum root width after one and a half year**

maximum root width	indigenous species	exotic species
<1.0m	*Acacia mellifera* *Albizia anthelmintica* *Balanites aegyptiaca* *Berchemia discolor* *Terminalia prunioides*	*Terminalia mentalis*
1.0-1.5m	*Acacia sieberiana* *Croton megalocarpus* *Dalbergia melanoxylon* *Dovyalis cafra* *Faidherbia albida*	*Moringa oleifera*
1.5-2.0m	*Acacia senegal* *Tamarindus indica* *Vitex doniana*	*Albizia lebbeck* *Azadirachta indica* *Casuarina equisetifolia* *Percea americana*
2.0-3.0m	*Acacia gerardii* *A. nilotica* *A. polyacantha* *Melia volkensii* *Terminalia brownii*	*Carica papaya* *Grevillea robusta* *Leucaena leucocephala* *Prosopis juliflora* *Psidium guajava* *Senna siamea* *S. spectabilis*
3.0-4.0m	*Acacia tortilis*	*Jacaranda mimosifolia*
>4.0m	*Cordia ovalis* *Ziziphus mauritiana*	*Acacia auriculliformis* *A. holosericea* *Eucalyptus paniculata*

5-5) Root width at top soil (above 40cm depth)

The root system of most of crops is mainly distributed in the top soil profile (above 40cm depth). Therefore, the trees which spread their root in the topsoil may compete for water with crops and may not be suitable species for intercropping agroforestry technology. Such species are; *Cordia ovalis, Acacia holosericea, Eucalyptus paniculata, Senna siamea,* and *Acacia auriculiformis* (Table 3). *Melia volkensii* is also described as an unsuitable species for intercropping agroforestry technology.

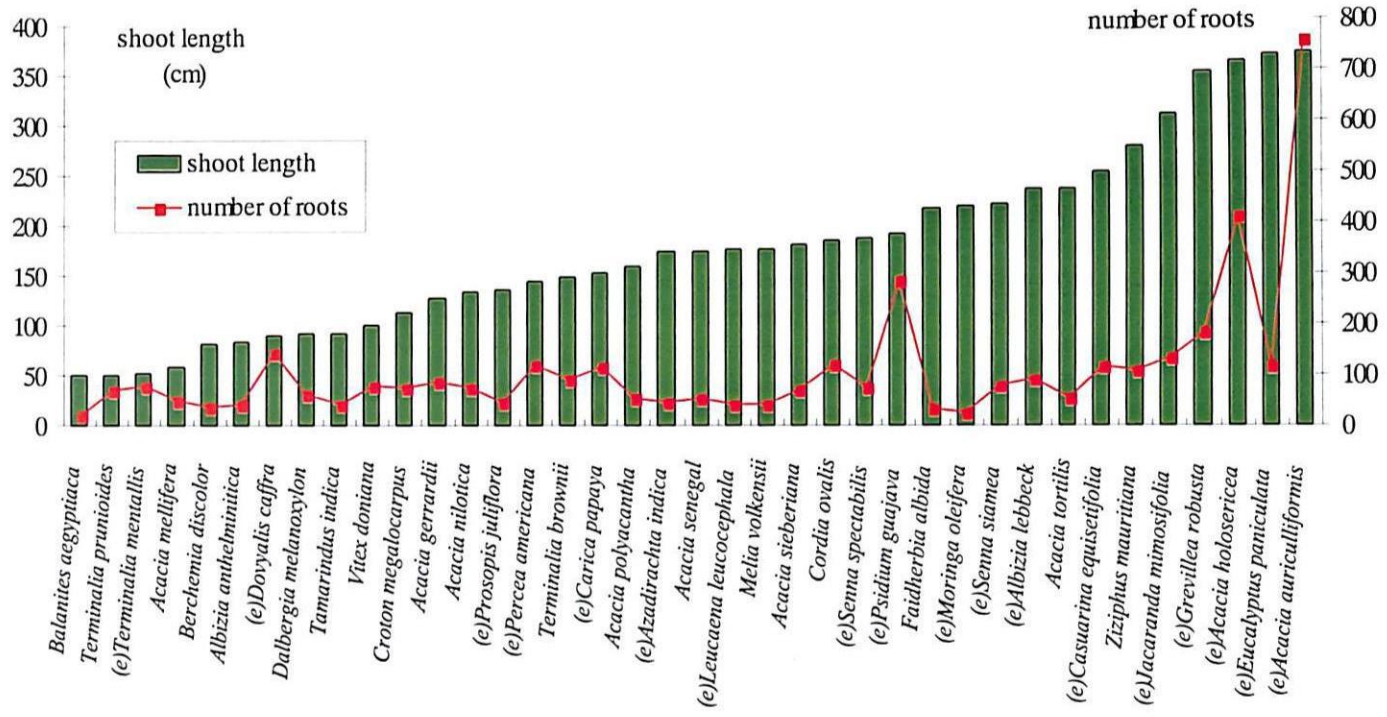
The trees whose root does not grow widely in the topsoil may competeless for water with crops. Most of indigenous *Acacia* species such as *Acacia gerardii, Acacia melifera,* and *Acacia tortilis* are included in this group as well as *Balanites aegyptiaca* and *Berchemia discolor* for. These trees are suitable for intercropping.

(Table 3) **Maximum root width at the top horizon of the profile soil (up to 40cm depth) after one and a half year**

Maximum root width	Indigenous species	exotic species
<1.0m	*Acacia gerardii* *Acacia melifera* *Acacia tortilis* *Balanites aegyptiaca* *Berchemia discolor*	*Terminalia mentalis*
1.0-2.0m	*Acacia nilotica* *Acacia senegal* *Acacia sieberiana* *Croton megalocarpus* *Dalbergia melanoxylon* *Dovyalis cafra* *Faidherbia albida* *Tamarindus indica* *Vitex doniana*	*Albizia lebbeck* *Azadirachta indica* *Casuarina equisetifolia* *Grevillea robusta* *Jacaranda mimosifolia* *Leucaena leucocephala* *Moringa oleifera* *Percea americana* *Psidium guajava* *Senna spectabilis*
2.0-3.0m	*Acacia polyacantha* *Melia volkensii* *Terminalia brownii* *Ziziphus mauritiana*	*Carica papaya* *Prosopis juliflora*
3.0-4.0m		*Acacia holosericea* *Eucalyptus paniculata* *Senna siamea*
>4.0m	*Cordia ovalis*	*Acacia auriculliformis*

5-6) Root density and growth rates

The root density was measured by counting the number of both main and small root at different soil profile (0-20cm, 20-50cm and 50-75cm) (Fig.7). It was observed that fast growing species have relatively high root densities. However, it is still early to be conclusive and further observation is still needed.



(Fig.7)Shoot length and root density (1 and a half year after planting)

((e):exotic species)

6. SPECIES DESCRIPTION

A) Indigenous species

A-1) *Acacia gerrardii*

General description A tree of 15m, may be smaller, somewhat flattened or, irregular crown with deeply fluted trunk. The bark is rough, grey-brown grooved. The thorns are very short, straight and hooked. Leaves are hairy. The flowers are rounded with cream heads. The pods are brown, slightly curved.
Ecology and distribution Widely distributed in wooded grassland, woodland especially in middle altitude, 1300-2200 m, usually riverine, in arid and semi-arid areas. Common in black cotton soils and 450-1100mm of rain per annum.
Uses Charcoal, timber, poles/posts, carving. Edible gum, fodder, shade and soil improvement (nitrogen fixing).

The tree attained a height of 49cm and a depth of 143cm giving a T:R ratio of 0.35 in 6 months. The shoot increased to 237cm giving a T:R ratio of 0:57.

- Three main roots grow straight, then spread widely. It has many sub and small roots. The root width is 235cm.
- The dry biomass ratio of 3.43 is by far higher than the recommended range of 1.0-1.5 for ASAL species. This may therefore imply that the tree would require more moisture for it to survive well in dry areas. Alternatively, the tree may have to loose many leaves for it to survive during extensive drought.

A-2) *Acacia mellifera*

General description A glabrous shrub or small tree exceptionally over 9m height. The branchelets are ash grey to pale brown with paired recurved thorns. The leaves are composed of 2-3 pairs of pinnae and 1-2 pairs of leaflets, which are obovate and very unequal, sized at the base. The flowers are cream or yellowish, white, often purplish in bud. The pods are greenish yellow to pale brown.
Ecology and distribution Widespread in eco-climatic zones (V-VI) from 0-1800 m especially in dry bush land with up to 800mm rainfall. It is one of the most drought resistant trees in Kitui area. It may be found in a variety of soils including gravelly, loam volcanic and sandy soils.
Uses Charcoal, timber, edible gum fodder, bee-forage and nitrogen fixing. Tree support edible *Hydnora abyssinica*.

- The root length is 211cm while shoot height is 58cm one and a half year after planted. The shoot/root ratio is 0.26, which is the second among all surveyed species.
- Three or four main roots grow down straight. The number of sub roots is 20 to 30. It also has lots of small roots. Sub roots spread horizontally in top of the soil. As a whole, root system is narrow and deeper.
- The shoot weight is 150g and root weight is 99g (1 and a half year). The shoot and root

weight ratio (T/R) is 1.5. The dry weight (biomass) ratio at one and half years after planting was 1.33.

- The shoot grows slowly but root grows fast which is 154cm in 6 month. Root depth of weeds is 20 to 30cm commonly and is at most 100cm. The main roots were 3, very deep with very few root lets. This is an adaptation for survival in dry areas. The nature of leaves, branches possess little competition for light. Deep rooting system is an advantage in agroforestry systems. The tree has a high potential for agroforestry and is drought resistant.

A-3) *Acacia nilotica*

General description A small thorny tree up to 5m tall. The bark is blackish deeply cracking. Flowers are bright yellow in heads. Pods are jointed straight or slightly curved rounded at both ends, exuding a whitish gummy fluid when squeezed. It drops leaves during the dry season.

Ecology and distribution An exceedingly variable species with many subspecies common from India to the semi-arid areas of Africa. Can grow on a wide variety of soils, from coastal sandy soils to black cotton soils. From 0-2500 m. Widely distributed on Kenya in acacia bushland and wooded grassland. Often dominant species.

Uses Charcoal, poles, tools, carving, medicine, fodder, bee-forage, nitrogen fixation, soil conservation, soil stabilization, windbreak, gum, tannin.

- The tree attained a height of 49cm and a depth of 126cm giving a T:R ratio of 0.41 in 6 months. This increased to a height of 133cm and a depth of 210cm giving a new T:R ratio of 0:64 in one and half years.
- The dry biomass T:R ratio after one year is 2:06.
- The tree had six main roots with very few root lets. Crown is narrow and open giving little shadowing effects. The tree has a very high potential for agroforestry and is drought resistant.

A-4) *Acacia polyacantha*

General description A tree to 20 m with feathery foliage. The bark is ash-grey or pale yellow pealing, old trees deeply grooved. Prickles are in pairs, hooked, brown with black tips. Flowers are creamy in spikes. Pods are flat persisting on the tree for a long period and consisting about six seeds.

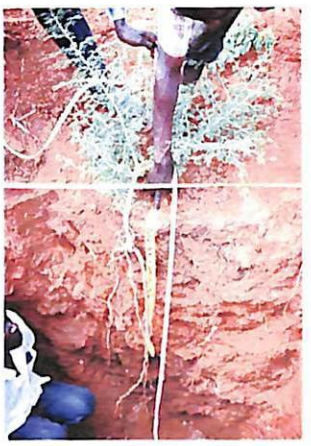
Ecology and distribution An upright acacia spreading in tropical Africa. Several varieties existing. Widespread, especially in riverine forest, woodland, wooded grassland often in areas with impended drainage in eco-climatic zone (IV), 600-1100mm of annual rainfall.

Uses Timber, tool handles, medicine, gum edible, fodder, charcoal, firewood, nitrogen fixation.

- The tree attained a height of 47cm and a depth of 103cm in 6 months increasing to 150cm top and 225cm depth in one and half years after planting. The root width is 262cm.

- The shoot/root length ratio is 0.77.
- The shoot weight is 724g and the root weight is 435g. The dry biomass T/R ratio is 1.98 at one and half years of planting. The high (362g) of dry biomass shoot to (195g) root may not be very appropriate in dry land afforestation especially in periods of prolonged drought. The high biomass production demands more moisture and nutrients. The spreading nature of the roots and shoot may not be very appropriate for agroforestry. However this tree may be very appropriate for firewood, poles etc.

A-5) *Acacia senegal*



General description Much branched shrub or small tree to 12 m tall. The bark is black, pale-brown, peeling yellow and papery. Hooks are threes, the central one hooked backwards and the other two directed forward. Flowers in silk cream sweetly scented, buds red. Pods flat, brownish with grayish brown seeds.
Ecology and distribution It is a slow growing species and a multiple-use tree suitable for dry areas. Widespread in arid and semi-arid areas of Kenya (eco-climatic zones III-VII), 150-1100mm of rainfall. Often forms a dominant species on raised rocky ground in very dry areas 100-1700 m. Prefers well-drained soils, especially rocky, loam or sandy soils.
Uses Charcoal, poles/posts, tool handles, edible gum, medicine, fodder (foliage and pods), soil conservation, fibre and gum.

- It spreads root deeper but not wider. The tree attained a height of 73cm and a depth of 178cm in 6 months. This increased to 173cm height and 254cm depth one and a half year after planted. The shoot/root length ratio is 0.71.
- The shoot weight is 3768g while the root weight is 1051g. The shoot/root weight ratio is 3.07, which is relatively high among the indigenous *Acacia* species. The dry biomass T:R ratio is 2:89 in one and half years after planting.
- It has four or five main roots and about 20 sub-roots. The rooting pattern (narrow and deep) improves the potential of this species for agroforestry. Crown spread reaching 170cm may require the establishment of crops to be at 2m distance from the stem to reduce shading effects.

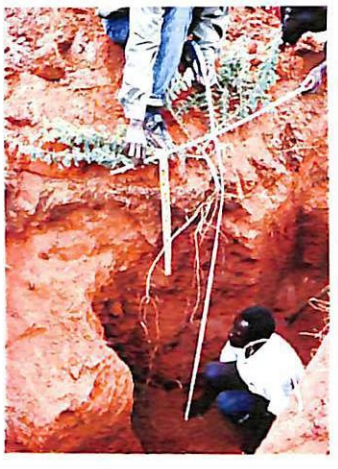
A-6) *Acacia sieberiana*

General description A tree 3-25 m tall with a rather round crown. Bark rough, yellow, flaking off in small, rectangular, grey brown scales. Leaves usually sparcely hairy, branched into small clusters 6-23 (max. 35) pairs of pinnae. Flowers cream, white or pale yellow.
Ecology and distribution Grow in the savannah and woodland. It occurs with various botanical characteristics in the entire Sahel and other semi-arid regions of Africa. Various varieties and local races exist, suited for riverbanks or low ground. It is drough resistant. Altitude 0-1850 m, mean annual rainfall 400-800 mm. Grows on deep, well drained, heavy clay, light sandy and medium loamy soils of acidic reaction.
Uses Produce edible gum, fodder, bee forage, firewood and charcoal,

fire, timber termite resistant, medicine.

- The root does not spread wide as the root length is 214cm and the width is 130cm after one and a half year.
- The shoot length is 180cm. The shoot/root length ratio is 0.89.
- The shoot weight is 2550g while the root weight is 775g. The T/R ratio is 3.95, which is rather higher among the indigenous species. A dry biomass T/R ratio is 2.9.
- The high T:R ratio(2.9) may be a disadvantage in using this tree for ASAL afforestation. The spreading crown may not be appropriate for agroforestry however with some management e.g. pruning, this may improve the potential of this tree for agroforestry.

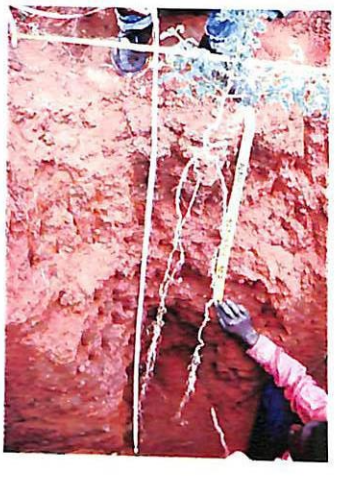
A-7) *Acacia tortillis*



General description Flat topped Acacia tree up to 10m height with gray-black cracked bark. The spines are short, hooked and long straight. The flowers are white or cream.
Ecology and distribution A common acacia in Africa. Found in arid or semi-arid of Kenya particularly in the grassland, riverine vegetation, along luggas, aridland scrub in a variety of soils from sandy, silt to black-cotton soil. Eco-climatic zones (IV-VII), 150-1100mm rainfall.
Uses Charcoal, timber, poles, medicine, fodder (leaves and pods), bee-forage, shade, dune fixation, nitrogen fixation, soil conservation, fibre.

- The tree attained a height of 88cm and a depth of 176cm in 6 months. This increased to 234cm height and 275cm depth in one and half years after planting. The shoot/root length ratio is 0.91.
- The shoot weight is 2388g while the root weight is 900g. The T/R ratio is 2.61. The dry biomass T:R ratio was 2:78 at one and half.
- The tree had 4 main roots spreading out with depth. Then the root spread widely in the deep area. Since it does not spread root in the topsoil, it may not compete for water with crops.
- The rooting pattern and the fact that the tree drops its leaves during the wet season improves the potential of this species as an agroforestry species in ASALs.

A-8) *Albizia anthelmintica*



General description A. *anthelmintica* is in the family Fabaceae-Mimosoidae. It is a glabrous deciduous bush or tree to 8 m. Bark is smooth and gray.
Ecology and distribution The species is widely spread in dry savanna except in the Rift Valley and Nyanza Provinces.
Uses It is nitrogen-fixing therefore can be used as mulch or green manure. It has medicinal both for livestock and human. It is particularly, important in de-worming.

- The root grows not wider but deeper. Compared to the shoot growth, the root grows very well as the shoot length is 83cm and the root length is 260cm after one and a half years.
- The shoot weight is 241g and the root weight is 231g. The T/R ratio

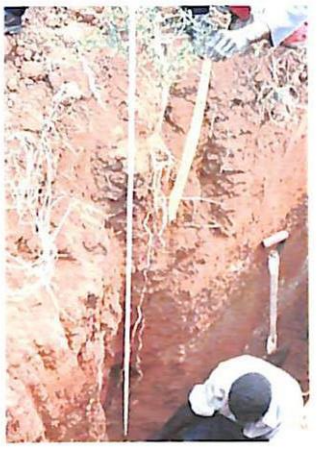
is 1.05.

- Two or three main roots grow deeply. As the root does not grows wide, this species may not compete water with crops.

A-9) *Balanites aegyptiaca*

General description *B. aegyptiaca* is in the family *Balanitaceae*. The adult form is a multibranched, spiny shrub or tree up to 10 m high. Leaves compound and spirally arranged on the shoots, dark green with 2 firm coriaceous leaflets. The fruit ellipsoid up to 4 cm long, green. Ripe fruit brown or pale brown with a brittle coat enclosing a brown or brown-grey sticky pulp and a hard stone seed.

Ecology and distribution *B. aegyptiaca* has a wide ecological distribution, it reaches maximum development on low-lying, level alluvial sites with deep sandy loam and uninterrupted access to water such as valley floors, riverbanks or the foot of rocky slopes. It occurs from 0 – 1,000 m, mean annual temperature of 20 – 30 ºC and mean annual rainfall of 250 – 400 mm.



Uses The fleshy pulp of both unripe and ripe fruit is edible and eaten dried or fresh. Livestock eats all the fresh and dried leaves, fruit and sprouts. The wood is good for firewood and high quality charcoal. The kernels produce edible oil used for cooking. An emulsion made from the fruit or bark is lethal to fresh water snails that are the host of miracidal and cercaria stages of bilharzia and to a water flea that acts as a host to the guinea worm. Decoction of root is used to treat malaria. Roots boiled in soup used against oedema and stomach pains. Roots are used as an emetic, bark infusion used to treat heartburn.

- The shoot length is 50cm while the root length is 167cm one and a half-year after planted. The root does not grow wider as the width of the root is 68cm.
- The T/R ratio (shoot and root weight ratio) is 1.35 which means the root weight (48g) is rather heavier than the shoot weight (57g) compared to other species.
- Two or three main roots grow vertically and narrowly. The number of roots is not so many.

A-10) *Berchemia discolor*

General description *B.dicolor* is in the family *Rhamnaceae*. A semi-deciduous shrub or tall tree to 18 m with straight bole and erect spreading branches making a heavy rounded crown. Leaves alternate or sub-opposite, entire or obscurely crenate, shiny above, dull and glaucous below.

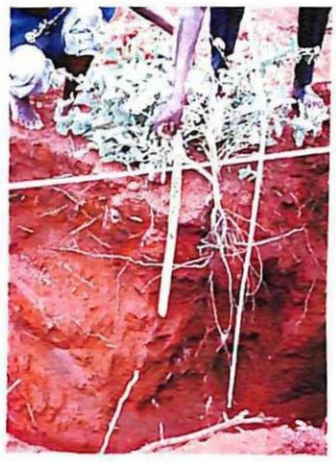
Ecology and distribution The species is widespread in arid and semi-arid areas from Sudan to South Africa, scattered, grows in open dry woodland or at lower altitudes along river valleys. *B. discolor* tolerate drought but is not resistant to frost or cold wind. The biophysical limits is 300-1900 m above sea level, mean annual temperature of 14-30 deg. C and mean annual rainfall of 250 to 1200 mm. It grows naturally in a variety of soil types but perform best on well-drained soils in woodlands and along drainage lines.

Uses The species has a variety of uses including timber, poles, furniture, construction wood,

fruit (raw or boiled with sorghum), tea (from leaves), fodder (fruit and leaves), bee-forage, ornamental, shade, windbreaks, resin, black dyes (powdered heartwood and roots). Roots have various medicinal uses.

- It is a slow growing species. Both shoot and root grows slowly as the shoot length is 81cm while the root length is 143cm one year and a half after planted.
- The shoot weight is 84g and the root weight is 155g. The shoot/root weight ratio is 0.73, which is relatively low.

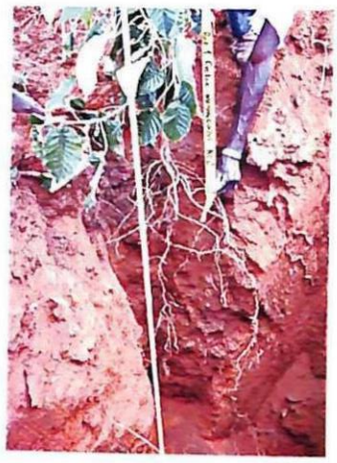
A-11) *Cordia ovalis*



General description C. *monoica (C.ovalis)* is in the family Boraginaceae. It is a multi-stemmed shrub or tree to 6 m, occasionally to 12 m. the leaves are broadly oval to almost round, 5-8 cm long, margin slightly toothed, surface above like sandpaper to the touch but softly hairy below with prominent veins.
Ecology and distribution Grows naturally from Eritrea to southern Africa. It is found in many habitats from wet or riverine forest to woodland and bush from coast to 2000 m.
Uses Firewood, poles, tool handles, bee-forage, leaves are used as sandpaper and the fruits are edible. Leaves and bark are medicinal.

- The root grows both deep and wide. The root length is 338cm and the root width is 603cm that is the widest among other species.
- The shoot length is 183cm after one and a half years. The shoot/root length ratio is 1.8.
- The T/R ratio is 4.06 as the shoot weight is 6027g while the root weight is 1486g. The T/R ratio is relatively high among the other indigenous species.
- There are many sub-roots around the topsoil. Besides, the root grows wider. So, it seems that this species competes water with crops.

A-12) *Croton megalocarpus*



General description *C. megalocarpus* is in the family *Euphorbiaceae*. It grows to 15-35 m, it has distinctive layering branches and a rather flat crown. Hardy and fast growing. Leaves are variable, long, oval and pointed to about 12 m. the dull green upper surface contrasts with the pale, silvery underside.
Ecology and distribution The species covers a wide range of habitats, including montane semi-evergreen forest and semitropical rainforest. It is a dominant upper storey tree in some forested areas, widespread from Kakamega, to Nyeri, Samburu, Taita. It grows between 1200-2450 m, mean annual temperature of 11-26ºC and mean annual rainfall of 800-1900 mm.
Uses It provides good fuel but the charcoal smoke can hurt the eyes. The bark has medicinal value. The seed is incorporated in poultry feeds, as its protein is high (50%). Leaves are high in nitrogen and phosphorus and serves as a source of mulch.

- The shoot length is 112cm while the root length is 165cm after one and a half years.

- The number of the main root is about five, all of which is rather thin. The root width is 128cm and root density is high. Small roots developed well.
- The shoot and root weight ratio is 4.26 as the shoot weight is 665g and the root weight is 163g. It shows that this species is not so tolerant to dry.

A-13) *Dalbergia melanoxylon*

General description *D. melanoxylon* is in the family Papilionaceae. It is a small, heavily branched spiny shrub or tree, typically 4–8 m tall but occasionally reaching 15 m. The bole is fluted with high narrow ribs separated by deep indentations. Bole length occasionally reaches 3.6 m but normally ranges within 0.2-1.8 m. Average diameter at breast height (dbh) for mature tree is less than 38 cm, although trees have been found with a dbh of more than 60 cm.

Ecology and distribution It grows under a wide range of conditions including semi-arid, subhumid and tropical lowland areas. It is often found on dry, rocky sites but is most frequent in the mixed deciduous forests and savanna of the coastal region. The tree demands water and light and therefore is common near water and will not regenerate under heavy cover. Mature trees are fire tolerant. The species grows within an altitude of 0-1200 m, mean annual temperature of 18-35ºC mean annual rainfall of 700-1200 mm. The soil conditions vary from loamy sands to clay vertisols (black cotton soils).

Uses It produces what is probably the most valuable timber by weight and volume in East Africa. The heartwood is hard, heavy and very durable. A prized wood among the Kamba carvers and European instrument makers, the trees have been reduced greatly in numbers. The pods and leaves can be used as animal fodder.

- The shoot length is 132cm while the root length is 213cm after one and a half years. The root grows much more than the shoot.
- Four to five main roots grow straight to deep soil. The shoot weight is 484g and the root weight is 368g. The T/R ratio is relatively low as it is 1.32.

A-14) *Faidherbia albida*

General description Tall spiny tree attaining 20m in height. Bark is gray and cracked. Branchlets are zigzag almost whitish. Spines are paired slightly pointing downwards. Flowers are cream and sweetly scented. Pods are orange-yellow, broad and twisted in various shapes.

Ecology and distribution found from Middle East to Namibia. In Kenya, it is found in semi-arid and riverine zones of arid areas. Flood plains, 500-2000 m in eco-climatic zone (IV-VII), 150-1100mm of annual rainfall.

Uses Both pods and leaves used as a fodder. Poles, utensils, medicine, seasoning, fodder, mulch, nitrogen fixing, soil conservation and windbreak.

- The tree attained a height of 69 cm and a depth of 177 cm giving a T:R ratio of 0:39 within 6

months. This increased to 215cm top and 343 cm depth giving a T:R ratio of 0:65 one and half years after planting. The root grows very deep but does not spread wide.

- The dry biomass increased from a ratio of 0.81 in 6 months to 1.23 in one and half years after planting.
- The number of main roots was 3 during the period of observation. The tree had very few rootlets. The main rooting pattern was narrow and deep. Such growth pattern implicates that the tree has a very high potential for survival and agroforestry in the dry areas as it possess little competition for moisture to other crops (agrocrops) given its narrow and deep rooting pattern with few rootlets in the top 100cm of the soil profile.

A-15) *Grewia aricantha*

General description This is a much branched scrub which grows up to 4m. Mostly found in dry areas. Leaves have clear veins running from the center thick and somewhat hairy especially underneath. The leaf is also bicolour, below beneath is white-grey and surface a bit dark green. Fruits are round about 1cm big brown when ripe. Outer cover peels off when squeezed. The fruit contain 3-4 seeds in each.
Ecology and distribution Widespread in Kenya. Found in bushland 250-2200 m and rainfall 250-800 mm.
Uses Edible fruit, fibre, furniture and construction twigs.

- After the observation, this species seem to be deep rooted because the main roots had attained over 104cm down the soil profile with about 78, 49 & 20 roots within 20cm-50cm & 15cm down the profile six months after planting.

A-16) *Melia volkensii*

General description A deciduous tree, to 15m; branches hanging low, poor form if not well managed. Bark is grey and fairly smooth. Leaves are bright green, compound, with many leaflets narrowing at the tip.
Ecology and distribution A valuable tree of semi-arid areas in Kenya, from 0-1200 m.
Uses Timber,medicine, fodder,bee-forage,mulch, green manure, erosion control.

- Root grows horizontally up to about 330cm and 176cm down the soil profile while the shoot grow 226cm within one and half years old. High root density found in 20cm deep zone.
- Thick main roots grow both widely and deeply. It creeps even near shallow soil profile above 50cm depth.
- The shoot and root weight ratio (T/R) is 2.06 as the shoot weight is 2,644g and root weight is 1,544g.

A-17) *Tamarindus indica*

General description An evergreen tree grows up to 30m. Crown dense widely spreading, rounded bark rough, fissured greyish-brown. Leaves alternate compound 10-18 pairs.
Ecology and distribution It is fairly slow growing but very long lived. It is also adaptable in wide area including the semi-arid area, It is believed to be indigenous to drier savannah of Tropical Africa
Uses Fruits are eaten raw or in porridge, leaves are vegetable, timber, charcoal, carving, medicine, shade.

- The root length after a half-year is not so long as it is 95cm. After one and half year, it is 219cm that show its root also grows slowly compared to other species. But the shoot grows less than half as it height is only 91cm.
- The root does not grow widely, the root weight is not so much as its length. The shoot and root weight ratio (T/R) is 1.4 after one and half year.
- Three to four main roots grow deeply. Small roots develop well in any part of the root system.
- As shoot growth is much less than the root growth and small root develops well, it survives well in the dry area.

A-18) *Terminalia brownii*

General description A deciduous tree, about 7-13 m, densely shady, somewhat layered, foliage drooping. Bark gray fissured young shoots hairy. Leaves fall down between May and October. Leaves are round and tiny, about 1cm around. It grows quite slowly.
Ecology and distribution It is one of the most drought resistant trees in Kitui area. Probably the commonest and most widespread *Terminalia* in Kenya. Occur in semi-arid areas 700-2000 m in woodland, bushy grassland and riverine forest. Prefers well-drained soils.
Uses Charcoal, timber, poles, posts, tool handles, medicine, fodder, shade, mulch, erosion control.

- The root length is 121cm while shoot height is 45cm after a half year. The root length is 199cm while shoot height is 147cm one and a half-year after planted.
- The shoot/root weight ratio is 1.97.
- Thick main roots develop both widely and deeply and attached many sub or small roots.

A-19) *Terminalia prunioides*

General description A deciduous tree 3-10 m tall. Bark is gray and older bark is grooved and ridged.
Ecology and distribution It is found in coastal forest and in very dry parts of Kenya from 0-1400 m.

Uses Timber, post/poles, tool handles, fodder, mulch, green manure.

- The root grows straightly deep rather than wide. The root length is 221cm while the shoot length is 50cm after one and a half-year. The root width is 38cm but is still wider than the shoot.
- The shoot weight is 47g while the root weight is 34g after one and a half-year. The shoot/root weight ratio is 1.25.

A-20) *Vitex doniana*

General description A\small or large tree, 8-18 m with a heaavy rounded crown and clear bole. Bark pale brown or grey white, with long fissures and scales. Leaves are opposite and compond, digitate-like long, tip rounded or notched.
Ecology and distribution A deciduous forest tree, widespread in East africa, largely found in coastal woodlands and savannah but also in low altitude wetter areas like Nyanza and upland grassland, 0-1800 m.
Uses Charcoal, timber, poles, carving, fruit/food, vegetable, medicine, fodder, bee-forage, shade , mulch.

- The root length is 173cm while shoot length is 100cm after one and half year. The root width is 197cm.
- The shoot weight is 1200g and the root weight is 813g. The shoot and root ratio (T/R) is 1.42.

A-21) *Ziziphus mauritiana*

General description A much branched, spiny tree, small but may reach 7 m, drooping angular branches, crown rounded. Bark grey, branches with curved thorns. Leaves alternate, shiny above, white below. Flowers small yellowish.
Ecology and distribution Now widespread in Africa, also Mediterranean to India. A common coastal tree 0-1400 m. It has a strong developed root system and does best in areas with a high water table.
Uses Charcoal, timber, poles, tool handles, carving, edible fruit, medicine, fodder, bee-forage, tannin, live fence, gum, dye.

- The root grows both deeper and wider compared to other species. The root length is 335cm and the width is 405cm after one and half year. The shoot length is 275cm. Both shoot and root grows very fast.
- The shoot weight is 6500g and the root weight is 2373g after one and half year. The shoot and root ratio (T/R) is 2.75.

B) Exiotic species

B-1) *Acacia auriculliformis*

General description It is a fast growing evergreen tree up to 15-30 m which originated from Australia. It has dense foliage with spreading crown. The trunk is crooked and the bark is vertically fissured.

Ecology and distribution It grows in a variety of soil ranging from coastal sand, sand loam as well as seasonally waterlogged.

Uses Fodder, bee-forage, fuel and timber and tannin.

The tree attained a height of 144cm and a depth of 206cm in 6 months. This increased to 366cm and 270cm height and depth respectively. The shoot/root length ratio is 1.55.

- The shoot weight is 13413g which is the second heaviest among the all species. The root weight is 4350g that is the heaviest among all. The T/R ratio is 1.55. Dry biomass ratio T/R as 2.94.
- The tree has a crown that spread out to approximately 3m and roots that spread out to 5m in one and half years. This coupled with the fact that the roots were concentrated on the upper surface and the numerous fibrous root systems this tree may not be appropriate for agroforestry in ASALs.

B-2) *Acacia holosericea*

General description A spreading thornless Acacia, 6m with ascending branches from a low base. The leaves have expanded leaf stalks. Flower small bright yellow cattail-like spikes. Pods are narrow and coiled in dense green clusters.

Ecology and distribution This is also a fast growing species that came from Australia in 1970s and grows well in arid and semi-arid areas. Tolerates a wide range of climates and soils from shallow acidic sandy lithosols, shallow loams, red volcanic and solodized solonets soils. Altitude 150-450 m and mean annual rainfall 600-1200 mm.

Uses Fodder and fuel

- The tree grew to a height of 84cm and a depth of 135cm in 6 months. This increased to a height of 358cm and a depth of 217cm in one and half years. Dry weight biomass gave T: R ratio of 6.34.
- The tree has many rootlets on the surface (0-20 and 20-50cm) depths that spread widely. This coupled with the fact that the tree has generally many roots makes this tree have many disadvantages both as an agroforestry species and one with the potential for use in ASAL afforestation.. The big crown implies more water demand hence not appropriate in periods of prolonged drought.

B-3) *Albizia lebbeck*

General description A. *lebbeck* is in the family Fabaceae – Mimosoidae. It can attain a

height of 30 m and a diameter of 1 m. More often it is 15-20 m tall with a diameter of 50 cm. It has compound leaves bipinnate, glabrous or slightly hairy on the axis.

Ecology and distribution It occurs extensively throughout the Indian subcontinent and in Thailand and Malays. As a common introduced roadside tree of the drier areas, it is widely cultivated and now naturalized in the West Indies and Africa. It grows from 0-1800 m altitude, mean annual temperature of 19-35ºC and mean annual rainfall of 500-2500 mm. It establishes well on fertile, well-drained loamy soils but poorly on heavy clays. Tolerates acidity, alkalinity, heavy and eroded soils, and waterlogged soils.

Uses Provide fodder for livestock, bee-forage, an excellent fuelwood species, timber, provide gum that is used as an adulterant of gum arabic, tannin. Have a variety of medicinal uses. Due to extensive fairly shallow root system, it is good for soil binding and recommended for eroded land. Provide shade for pasture as well as for tea and coffee plantations. Forms nitrogen-fixing nodules in the nursery without any inoculation treatment and fixes atmospheric nitrogen. Nitrogen-rich leaves are valuable as mulch and green manure.

- The root grows rather deeply than widely. The shoot length is 234cm and the root length is 213cm after one and a half years.
- The shoot weight is 1125g while the root weight is 1300g. The shoot/root weight ratio is 0.87, which is the third lowest among the other species. It shows that this species is drought tolerant.

B-4) *Azadirachta indica*

General description *Azadirachta indica* (Neem) is in the family. Neem has pinnate, green leaves with rough bark and cracked vertically, flowers are golden white or yellowish and fruits are slightly oval. The seed has smooth single kernel.

Ecology and distribution Neem is thought to have originated in Assam and Burma (where it is common throughout the central dry zone and the Siwalik Hills) . However, the exact origin is uncertain: some say neem is native to the whole Indian subcontinent; others attribute it to dry forest areas throughout all South and Southeast Asia, including Pakistan, Sri Lanka, Thailand, Malaysia, and Indonesia. It is in India that the tree is most widely used. The neem tree is famous for its drought resistance. Normally it thrives in areas with semi-arid to sub-humid conditions, with an annual rainfall between 400 to 1200 mm. It can also grow in regions with an annual rainfall below 400 mm, but in such cases it depends largely on the ground water. The species can grow between 0 to 1500 m above sea level and withstand mean annual temperature of up to 40°C, but it will not withstand freezing or extended cold. On the other hand neem cannot withstand "wet feet", and quickly dies if the site becomes waterlogged. It is believed that neem was introduced in Kenya in the beginning of the last century by Indian migrant workers during the building the Kenya-Uganda railways. Although no contemporary records exist, it is believed that these settlers brought with them seeds, which they planted for phytomedical purposes, particularly, in Mombasa district where many old neem trees are now to be found.

Uses Neem has a whole range of uses that makes it to be referred to as a wonder tree or as a tree for solving global problems. The uses range from pesticides, human and animal health (neem is known to have antifungal, antibacterial and antiviral, antimalaria activities), cosmetic

industry and environmental conservation role. Neem also provides timber for construction, furniture and carving.

- The root grows twice as the shoot length after a half year. After one and a half-year, the shoot length is 173cm and the root length is 169cm.
- Four to five main roots grow straight to the deep soil. Small roots are well developed.
- The shoot/root weight ratio is 1.54 as the shoot weight is 1044g and the root weight is 641g. The T/R ratio is relatively low.

B-5) *Carica papaya*

General description *C. papaya* is in the family Caricaceae. It is an evergreen tree-like herb, 2-10 m tall, usually unbranched, containing latex in all parts. It has an extensive rooting system. Leaves are spirally arranged, clustered near apex of trunk. Fruits are large cylindrical, with fleshy orange pulp, hollow berry and thin yellowish skin when ripe.

Ecology and distribution The genus *Carica* is indigenous to tropical America. *C. papaya* grows satisfactorily in a wide range of areas from the equatorial tropics to temperate latitudes from sea level to 1600 m and mean annual temperature between 21-33 deg. C. The species require mean annual rainfall from 1000 – 2000 mm but has been known to tolerate as low as 500 mm of rainfall. It requires a well-drained, permeable, well-aerated root-rot nematode free, fertile loamy soil preferably rich in organic matter with neutral reaction (pH 6-7).

Reproductive biology Pawpaw is propagated from seed. The tree has fast growth producing fruits within one year. Pawpaw is short-lived, decreasing in production after the plant is 4 years old. Usually male and female flowers are on different trees, but some flowers are bisexual.

Uses The fruit is not only useful when ripe but unripe pawpaw contains an enzyme called papain, which is an aid to digestion and is the main ingredient in meat tenderizer. Ripe fruit is a good source of vitamins, especially A and C. It can be used to make fruit salads, jam, jelly, marmalade, candies and crystallized fruit.

- The root does not go deeper but grows as wide as 275cm after a half year.
- The shoot weight is 1513g while the root weight is 988g after six months. Both shoot and root grow very fast especially in the first year.

B-6) *Casuarina equisetifolia*

General description C. *equisetifolia* is in the family Casuarinaceae. It is an evergreen, dioecious tree 6-35 m tall, with a finely branched crown. The crown shape initially conical but tends to flatten with age. Trunk straight, cylindrical, usually branchless for up to 10 m, occassionally with buttress. The minute, reduced, tooth-like leaves are in whorls of 7-8 per node.

Ecology and distribution It has the widest distribution of all Casuarina species and occur naturally on subtropical and tropical coastlines from northern Australia through Malaysia to Polynesia. The species is naturalized in Kenya. The extensive root material and association with *Frankia* enable the tree to grow in poor soils. The species is grow within altitude 0-1400 m, mean annual temperature of 10-35ºC and mean annual rainfall of 200-3500 mm. It grows

on soils, which are invariably well drained and rather coarse textured, principally sands and sand loam. The species tolerates both calcereous and slightly alkaline soils but is intolerant of prolonged waterlogging and may fail on poor sands where subsoil moisture conditions are unsatisfactory.

Uses It is used as timber, poles, mulch, sand stabilizer and soil reclaimer at the coast. It has high quality fire wood and also produce high-quality charcoal. A row of *C. equesitifolia* makes excellent windbreak. Good pulp can be obtained from the wood. It is used for soil erosion control along coastlines, estuaries, riverbanks and waterways. Root nodules containing the actinorhizal *Frankia* enable *C. equisetifolia* to fix atmospheric nitrogen.

- The shoot length is 251cm while the root length is 172cm. The shoot growth is rather higher than root growth compared to other species.
- The shoot weight is 1370g while the root weight is 402g. The T/R ratio is 3.43.

B-7) *Dovyalis caffra*

General description It is a thorny shrub or small evergreen tree with usually 3-5m height. Bark is grey with strong spikes up to 6cm. Leaves are thin, shiny dark green of about 5cm.
Ecology and distribution Found in open bush or wooded grassland above 1200 m.
Uses Live fence, ornamental. Fruits are round, orange yellow when ripe and edible by children.

- Root pattern deep rooted at age of one and half years extends up to about 260cm.
- More roots are observed within 50cm-75cm deep zones (about 79 & 36 respectively) only 29 roots were recorded within 20cm zone.
- Compared to the shoot length (90cm), its root grows deep up to 229cm after one and a half-year. The root does not spread wide.
- The shoot weight is 150g while the root weight is 97g. The T/R ratio 1.34 that is relatively lower among the exotic species.
- Since this species is evergreen it is expected to utilize a lot of water within the planted area.

B-8) *Eucaliptus paniculata*

General description This is a tall tree, conical when young, hardy but fairly slow growing. Bark is distinctive dark brown. Fruits are quite small up to 7cm long.
Uses The timber is very hard and resistant to decay. Firewood and charcoal

- Both shoot and root grows very well. The shoot length is 365cm, while the root length is 248cm and the width is 536cm after one and a half-year.
- The shoot weight is 13057g while the root weight is 3599g. The T/R ratio is 3.68.
- After one and half years more of the roots were observed between 20cm and 50cm below the soil profile. The main roots extended up to 125cm vertically and about 184cm

horizontally.

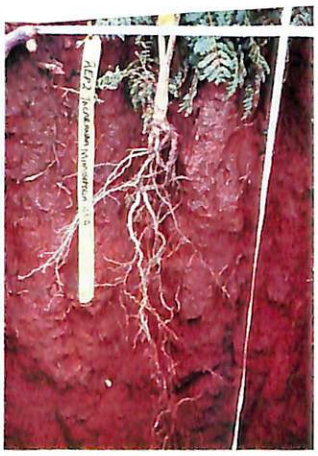
- Due to high density leaves and roots, a lot of water competition is expected with other surrounding plants.

B-9) *Grevillea robusta*

General description It is a semi-deciduous tree which grows up to 20m or even more with a straight trunk. Bark is dark grey, rough, vertically grooved. Leaves are fern-like very divided leathery pale green above and silvery green below. The fallen leaves are slow to decompose. Fruits are dark capsule about 1cm with a slender beak, splitting to set free 2 winged seeds.
Ecology and distribution Occur from 0-2300 m and rainfall of 600-1700 mm.
Uses Timber, shade for coffee plantation, firewood and charcoal, mulching,

- Within one and half years, spreading of roots are found within 20cm followed by 50cm and last 75cm (51:28:4) with average radius of 82cm. Taproot extended up to 223cm down the soil profile.
- The shoot length (223cm) is almost as same as its root length (213cm) after one and a half year. The root width is 269cm.
- The shoot weight is 8492g while the root weight is 2180g. The T/R ratio is 3.82, which implies that this species is not so tolerant to drought.

B-10) *Jacaranda mimosifolia*



General description This is a deciduous tree which grows up to 20m. Leaves look like fern and are feathery, tinny leaflets pointed. Flowers are striking mauve-blue dusters, each flower is bell shaped, tree is mostly in flower when not in leaf. Fruit are round woody capsule to about 7cm, splitting on tree to release numerous light seeds with transparent wings.
Ecology and distribution Native to Brazil and Argentina. 500-2400 m. Best in well-darined sandy loam soils and annual rainfall of 900-1300 mm
Uses Ornametal, timber, bee-forage and medicine.

- In one and half years after planting, it was observed that roots of this species can extend up to 260cm down the soil profile. More roots are observed within 20cm-50cm zones (about 45-65) as compared to 24 roots found within 75cm zone down the soil profile.
- The shoot weight is 6026g and the root weight is 3915g. The shoot/root weight ratio is 1.54 that is relatively low.

B-11) *Leucaena leucocephala*

General description This is an evergreen shrub which grows between 5m-20m depending

on climatic condition and soil types. Leaves are compound alternates with many leaflets, each thin and pointed to 1.5cm. Leaves and leaflets fold up with heat or lack of water. As it has a lot of leaves, water loss is quite high through evapotranspiration. Flower is white, round heads about 2cm across on along stalk from the leaf axial. Heavy seeder, pods are palatable to livestock especially goats when green.

Ecology and distribution Widespread in Mexico and Latin America. Was introduced in Kenya for Agroforestry. The tree was attacked heavily by Leucaena psyllid. Tolorate alkaline soils up to pH 8. Cannot tolerate acidic soils.

Uses Fodder, mulch, green manure, firewood

- It develops a deep taproot even as a seedling. Much of its roots are found within 20cm-50cm that is a crop zone (15-15) as compared to 10 within 75cm deep zone. Roots have nodules that fix nitrogen.
- The shoot length is 175cm while the root length is 232cm after one and a half-year.
- The shoot weight is 773g while the root weight is 424g. The T/R ratio is 1.75.

B-12)*Moringa oleifera*

General description This is a deciduous tree which grows up to 10m. Its bark is grey, thick and peeling in patches. Leaves are pale green with oval leaflets which are tip rounded, 1-2cm long. Fruits are long capsules of about 45cm, which are bluntly triangular in sections and slit when dry.

Ecology and distribution Grow from 0-1000m and rainfall of at least 500 mm per annum. Withstand a wide range of soils with well drainage. Does not tolerate waterlogging.

Uses Medicine, vegetable, water purification, fodder, bee-forage.

- Much of its roots are observed within 20cm-50cm zones (which is a crop zone) and extends its taproot up to 140cm down the soil profile after one and a half year. It can spread horizontally up to about 150cm Shoot root ratio is about 1:1.7.
- The root is one of the shortest among all species as it is 145cm after one and a half-year. Compared to the shoot length (216cm), its root does not grow well.
- However, the root weight is much more than its length as the main root is very thick. The shoot weight is 1185g while the root weight is 750g. The T/R ratio is 0.79 that is the second lowest among the all species. It means that this species is tolerant to drought.

B-13) *Percea americana*

General description This is a densely leafy evergreen tree to 10m. It has a grey-brown bark, with large alternating leaves up to 20cm long. Veins are clearly seen and young leaves look pinkish then bright green. Fruits are large and round shaped hanging loosely on the tree.

- One and half years after planting, spreading of roots of this species showed high root density with more concentrated in

20-50cm zones 66-36 compared to 75 cm down the soil profile where 20 roots were counted.

- The root is shallow, as the root length is 147cm after one and a half years.
- The shoot weight is 1588g and root weight is 375g. The T/R ratio is 4.33, which is higher among other species.

B-14) *Prosopis juliflora*

General description This is often a shrub but can become a shapely tree to 15m
Bark is thick, rough green grey and scaly with age. Leaves alternate and leaflets are narrow 1-5cm long Much of the leaves are crowded around the spikes. Fruits are yellow pods 10-20cm, which are sweet, hard seed which are difficult to extract.
Ecology and distribution Originated from Peru and widely planted in dry tropics. The tree has a potential of becoming invasive.
Uses firewood and charcoal, bee-forage, fodder, poles and posts, edible fruits

- Rooting pattern of these tree shows that it can grows extensively horizontally because after one and half years roots width was about 366cm and 224cm down the soil profile.
- High root densities are observed within 20-50cm as compared to 75cm down the soil profiles.

B-15) *Psidium guajava*

General description The guava is a small tree. It came from tropical America and now has become naturalized in Kenya. It rather tolerates drier area. Fruit is oval, turning bright pink and edible when ripe. Birds easily spread seeds.

Ecology and distribution Originated from American tropics. Is widely planted and almost naturalized in Kenya. It grow on a wide variety of soils including slight acidic from 1000-2000 m altitude.
Uses fruit, firewood and charcoal, bee-forage

- The root is shallow, as the average depth of the root is 163cm and width is 297cm after a year and half.
- There are many small roots spreading from top to bottom. The root weight (wet) is 700g while the shoot weight is 3,890g. T/R ratio is 5.50.

B-16) *Senna siamea*

General description This is a evergreen tree and fast growing trees, next to *Eucalyptus spp.*. Leaves consist of 8 to 13 pairs of leaflets whose shape is oblong with 1.5cm width and 4 to 5 cm lengths.
Ecology and distribution Originated in south and eastern Asia. Widespread in tropics where it was introduced from 0-1000 m and rainfall from 400 –2800 m.

Uses Firewood, charcoal, soil conservation, fodder, ornamental, bee-forage.

- Root(144cm) is longer than shoot(96cm) after 6 months while root(253cm) is shorter than shoot(287cm) after one and a half year. It has a lot of leaves. Root spreads wide to 273cm after a year and half, which is wider than the width of crown.
- The color of the root is black. About 6 thick main roots grow in any direction, horizontally and vertically. It was observed that roots penetrate murram layer and that root depth was over 300cm. The number of roots is many, 44 at 20cm depth, 75 at 50cm depth and 34 at 75cm. Many sub and small roots are observed especially top of the root system. Small roots also grow well in the topsoil.

- The shoot weight is 2901g and the root weight is 1506g. The shoot/root ratio (T/R) is 2.74, which is lower position among the surveyed species.
- As it has a lot of leaves, the quantity of water that evaporates from the tree seems quite a lot. It means that it consumes water much from the ground and competes with other plants and weeds for water. It suggests two things. One is that it is not good to plant crops near the tree. The other thing is that intensive water taking method is very useful to this species.

B-17) *Senna spectabilis*

General description It is a fast growing species. The leaves are shed from June to November. It experiences die-back if the circumstances becomes more dry. The leaves are compound up to 40cm in length. Leaflets are from 4 to 15 pairs, each up to 7.5cm.
Ecology and distribution Originated from tropical America and introduced in Asia as ornamental Grow upto 2000 m in deep moist sandy soil but can also grow in black cotton soil.
Uses Ornamental, soil conservation, firewood and charcoal, bee-forage

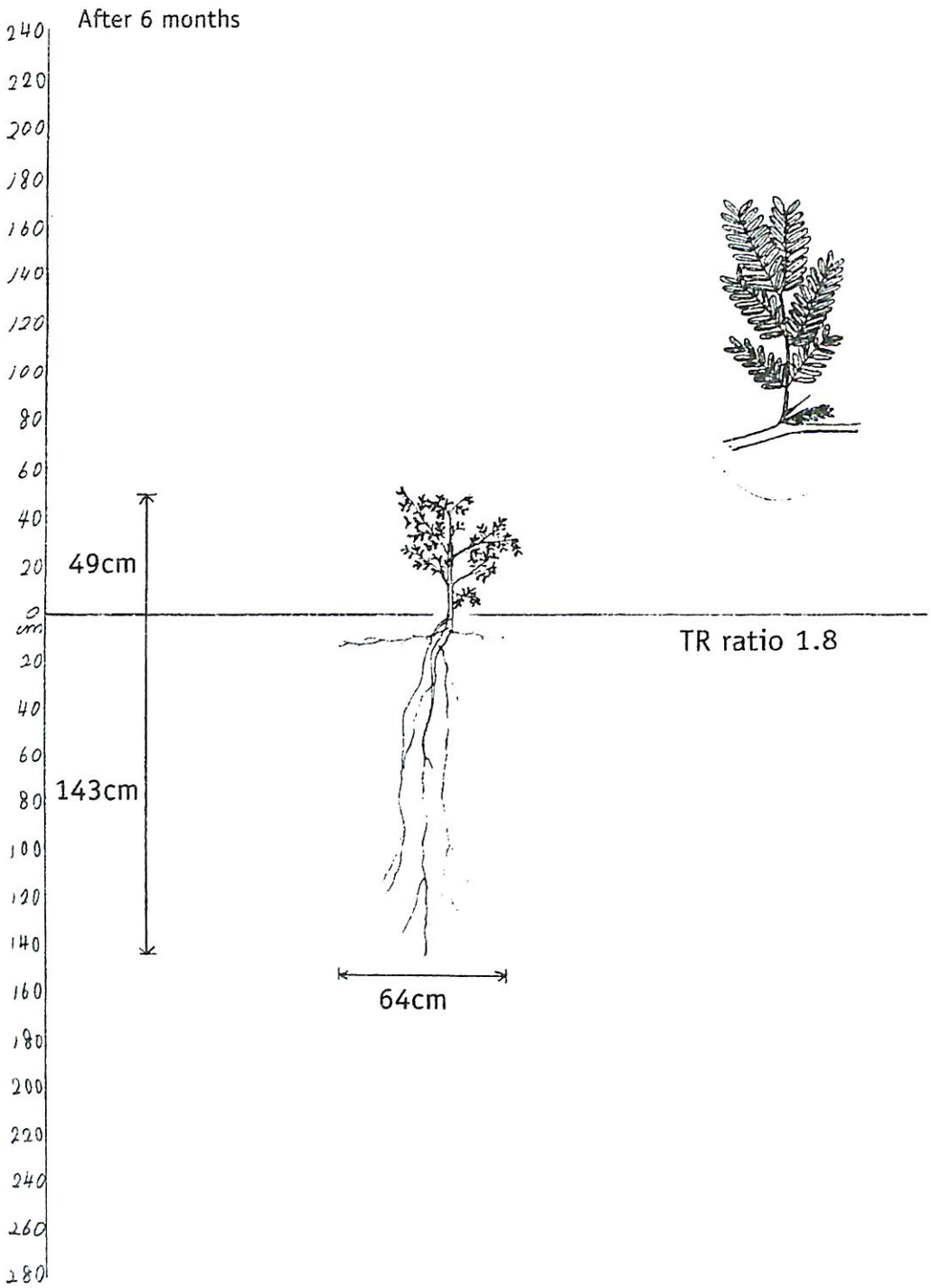
- The shoot length (185cm) is almost the same as the root length (163cm).
- There are five or six thick main roots and many sub-roots spreading radially. The width of roots is 231 cm. In general roots system develops well.
- T/R ratio is 3.34, as shoot weight is 1,056g while root weight is 333g.
- The growth of shoot is almost the same as that of roots. It grows very well next to *Senna siamea* where the moisture of the soil is enough. It photsynthesize well since it has a lot of leaves. However, it sheds leaves or causes die-back where soil moisture is not enough.

B-18) *Teminalia mentalis*

General description An evergreen tree which was usually planted as an ornamental tree with horizontal branches.
Ecology and distribution Introduced from Madagascar
Uses Ornamental

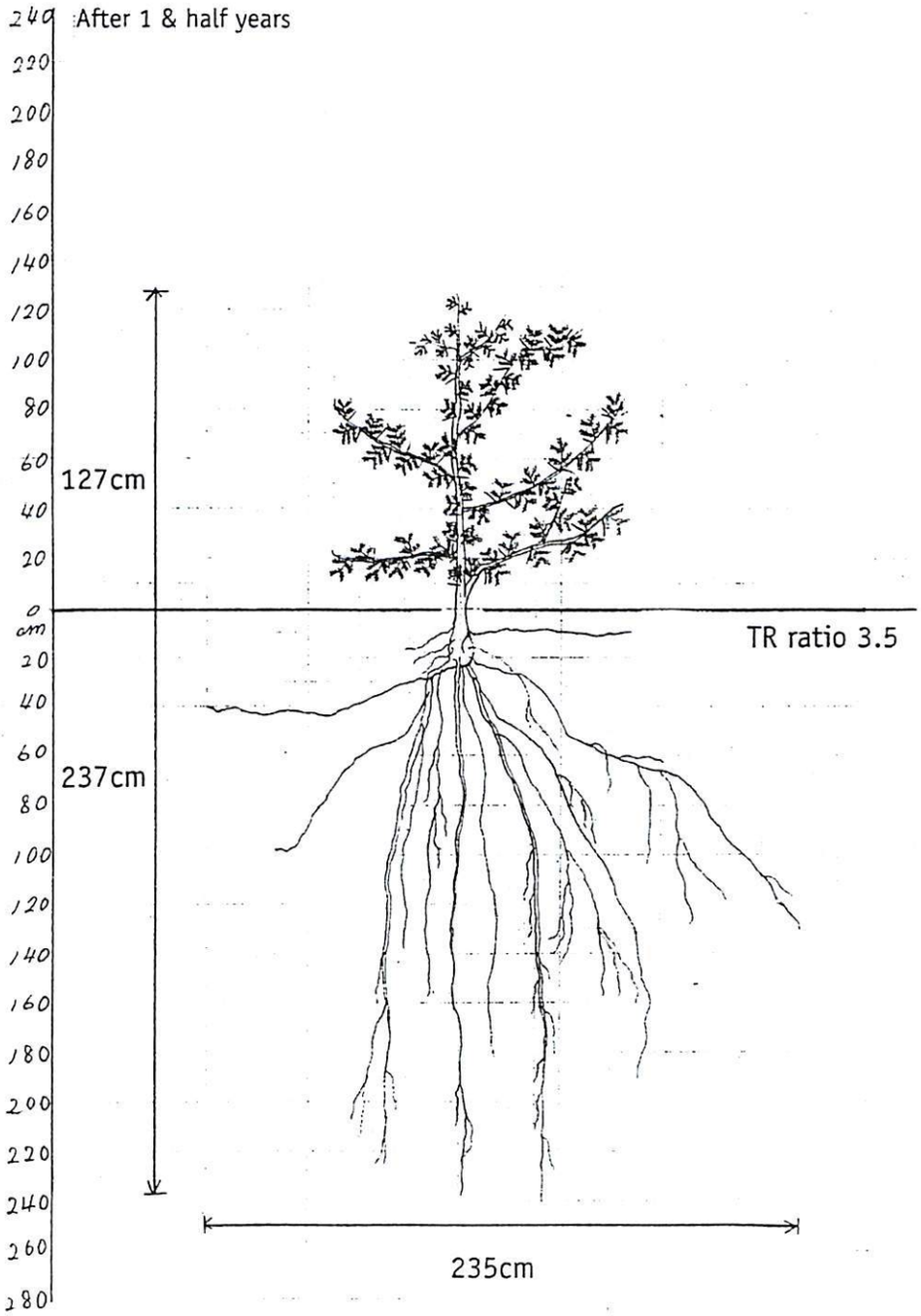
7. ILLUSTRATION OF ROOT SYSTEM

A-1) *Acacia gerrardii*



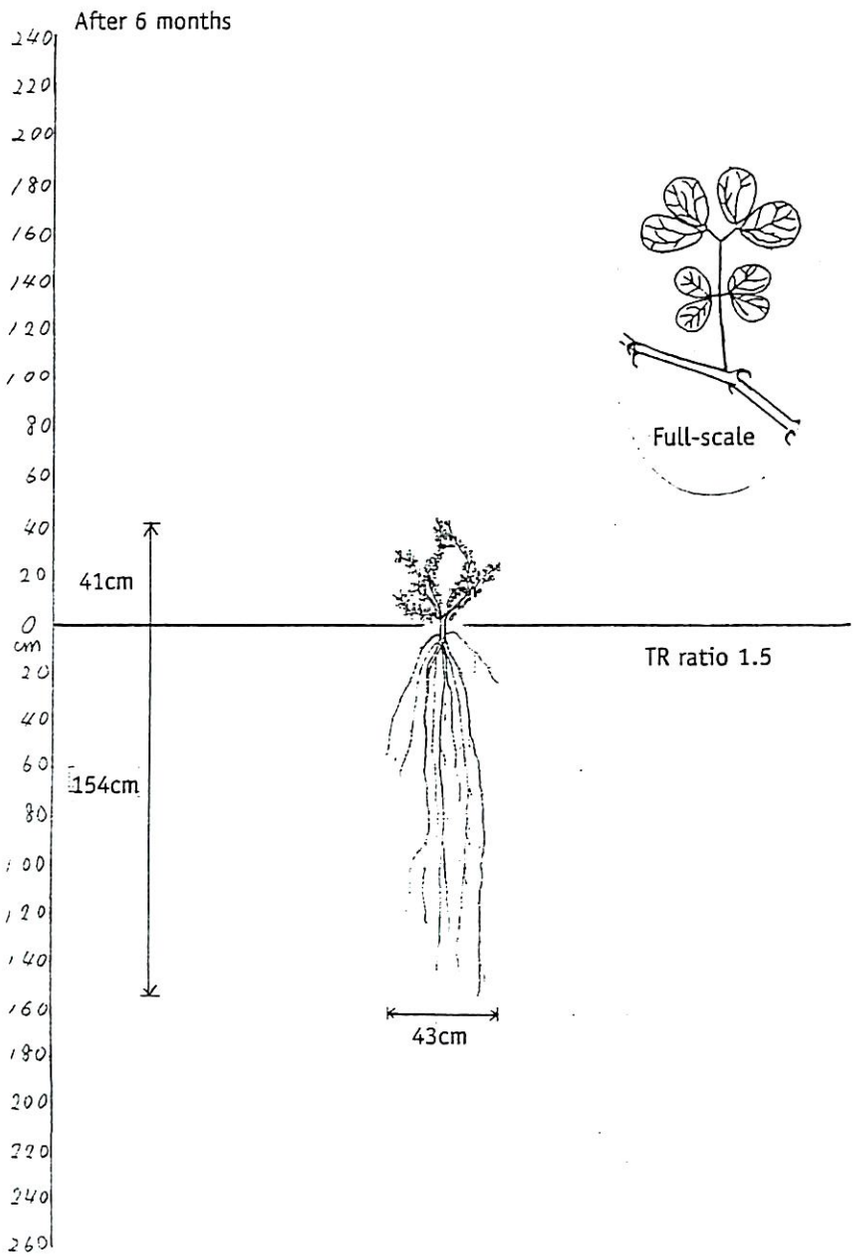
A-1) *Acacia gerrardii*

Acacia gerrardii



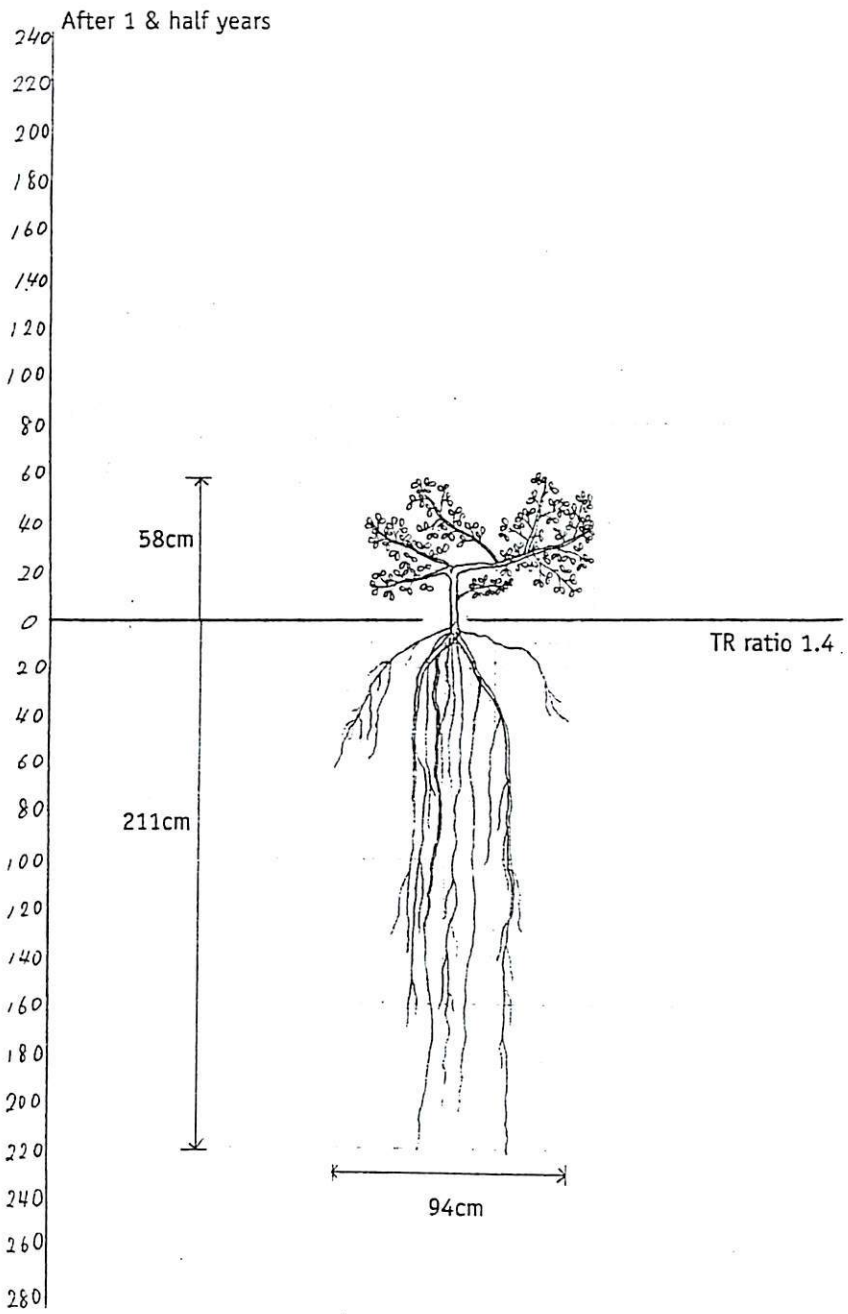
A-2) *Acacia mellifera*

Acacia mellifera



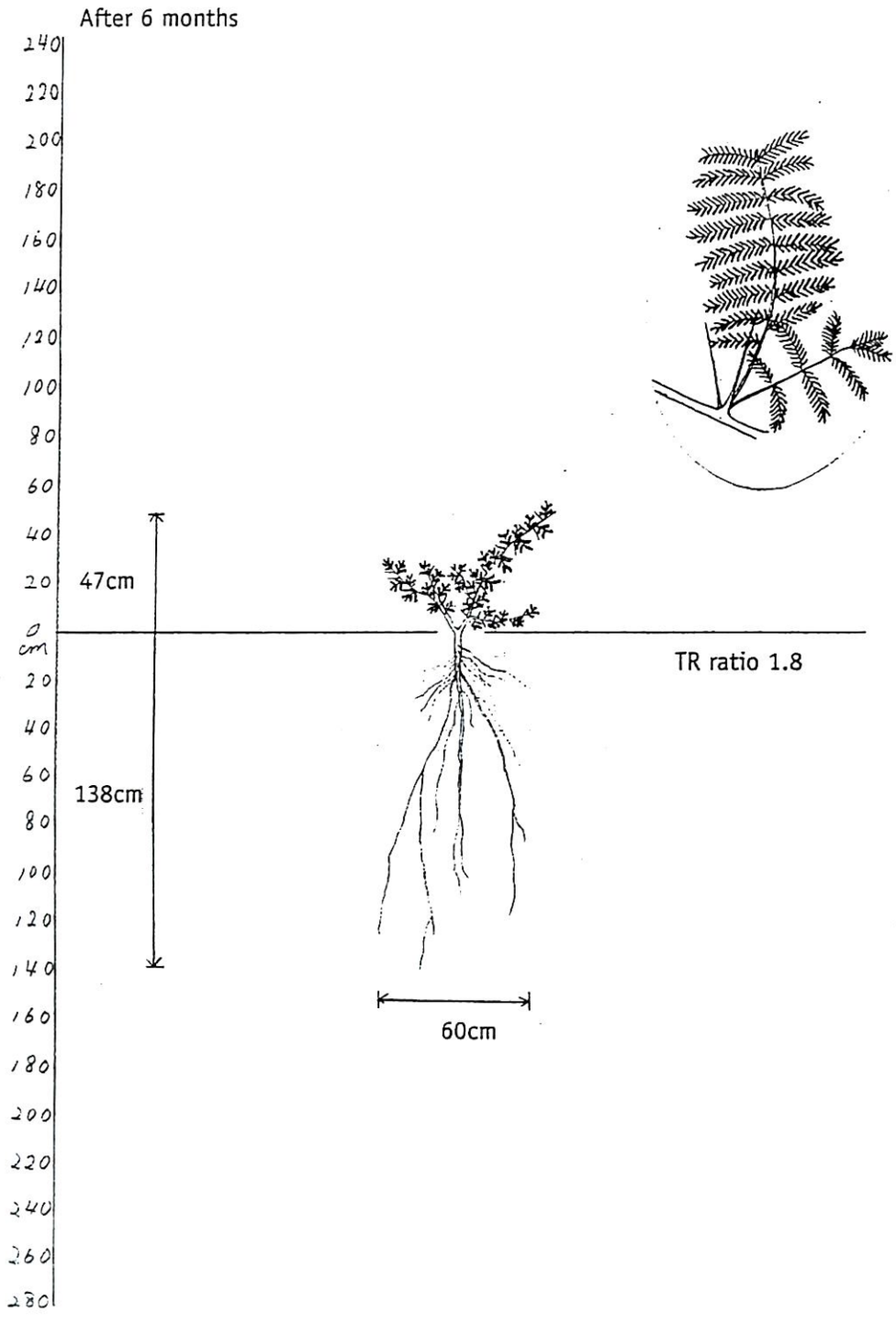
A-2) *Acacia mellifera*

Acacia mellifera



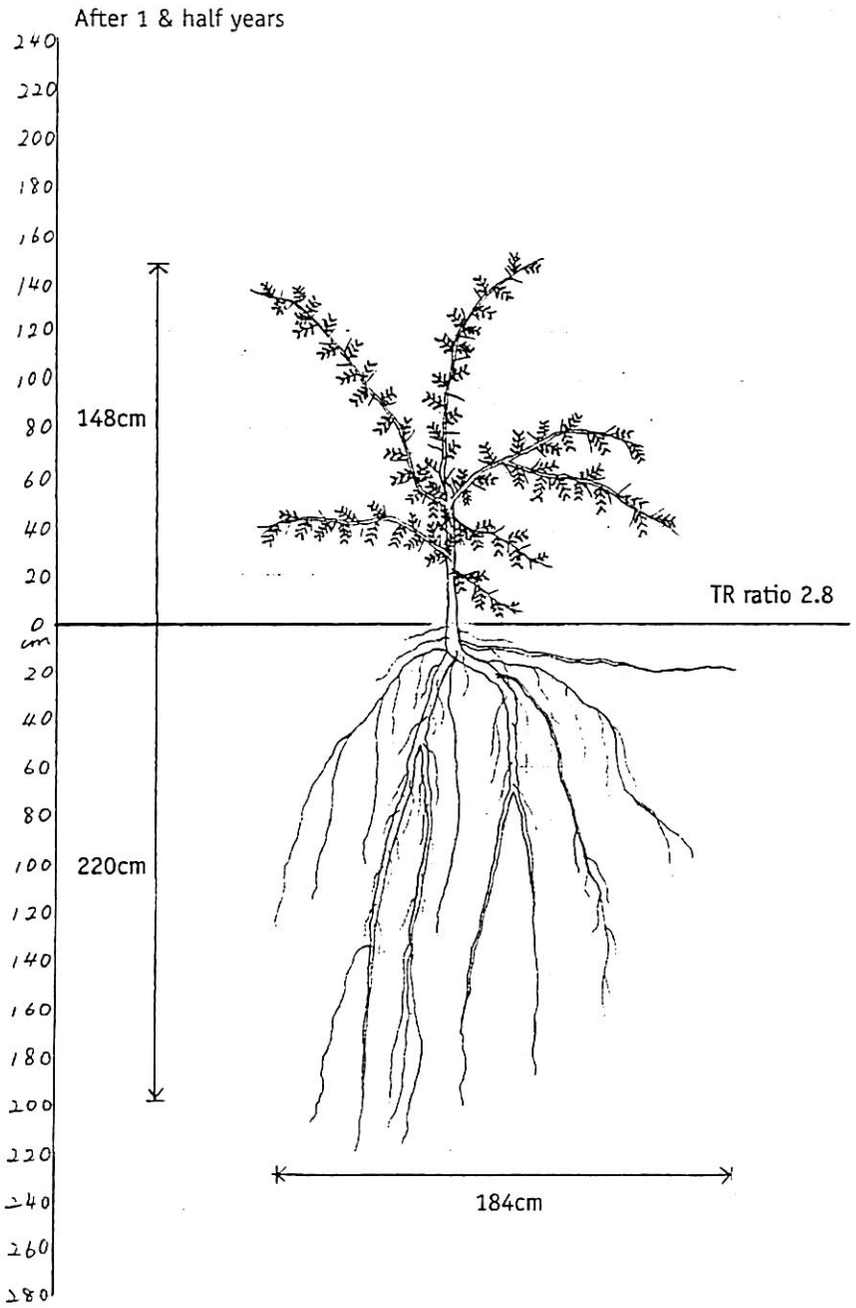
A-3) *Acacia nilotica*

Acacia nilotica



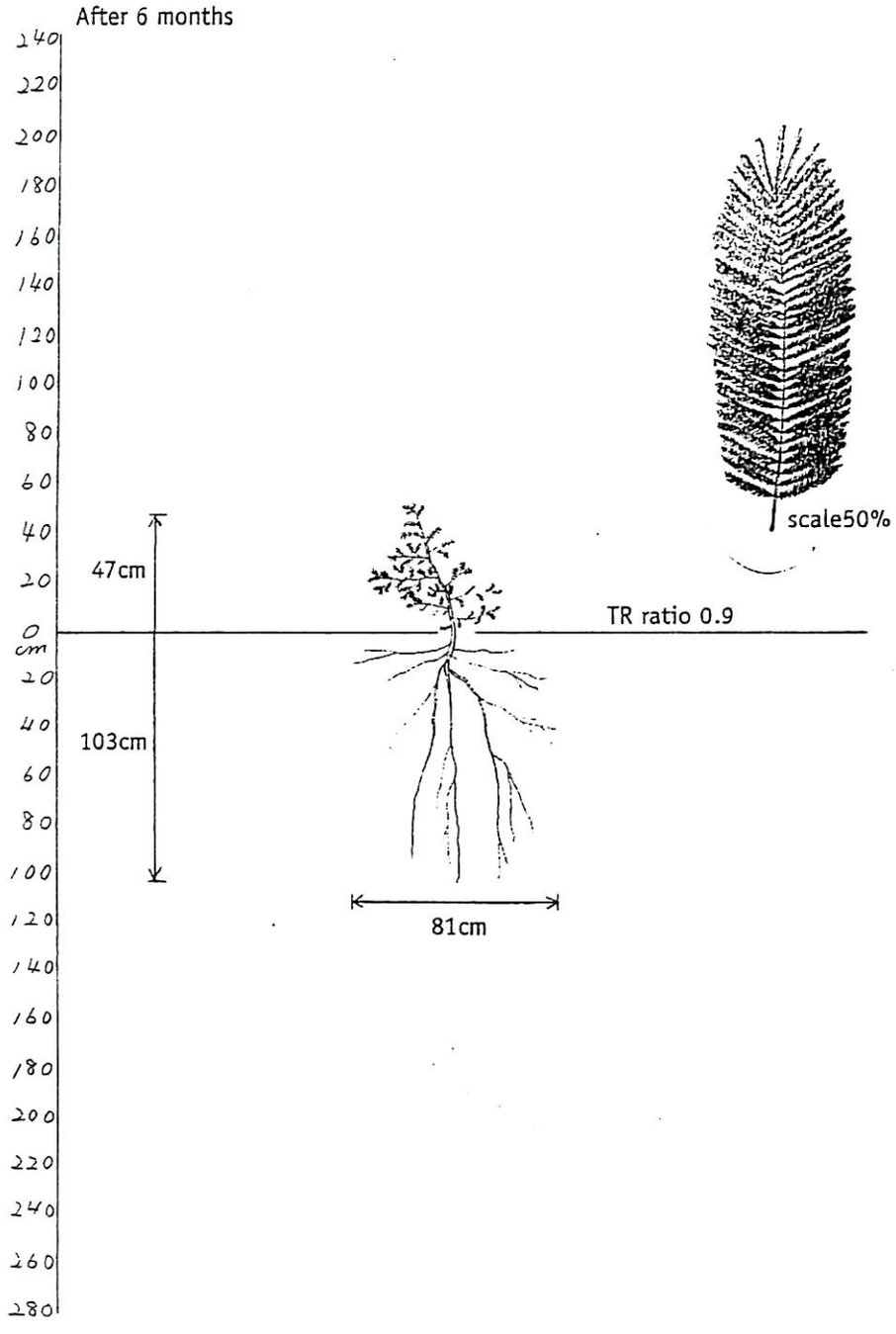
A-3) *Acacia nilotica*

Acacia nilotica



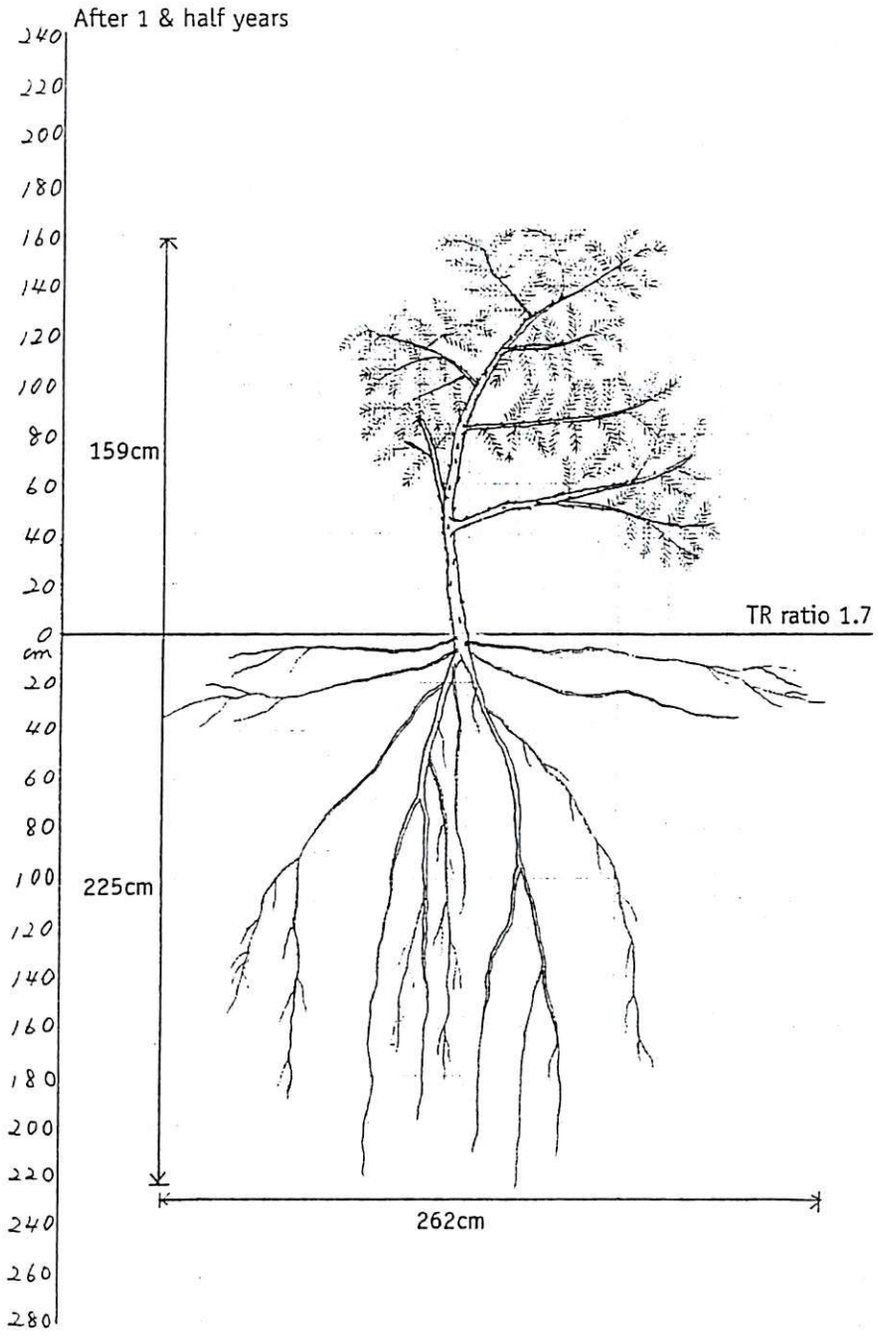
A-4) *Acacia polyacantha*

Acacia polyacantha



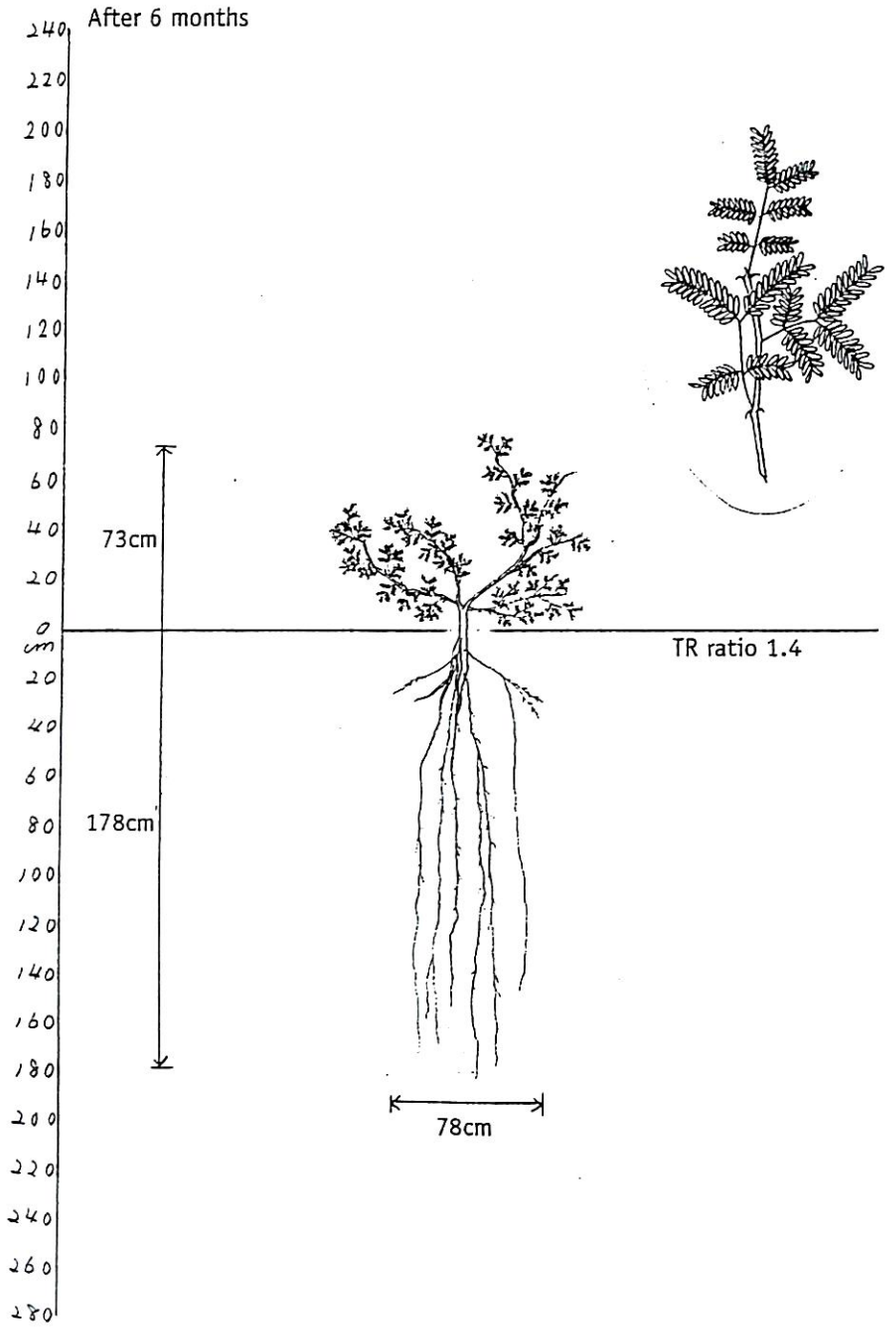
A-4) *Acacia polyacantha*

Acacia polyacantha

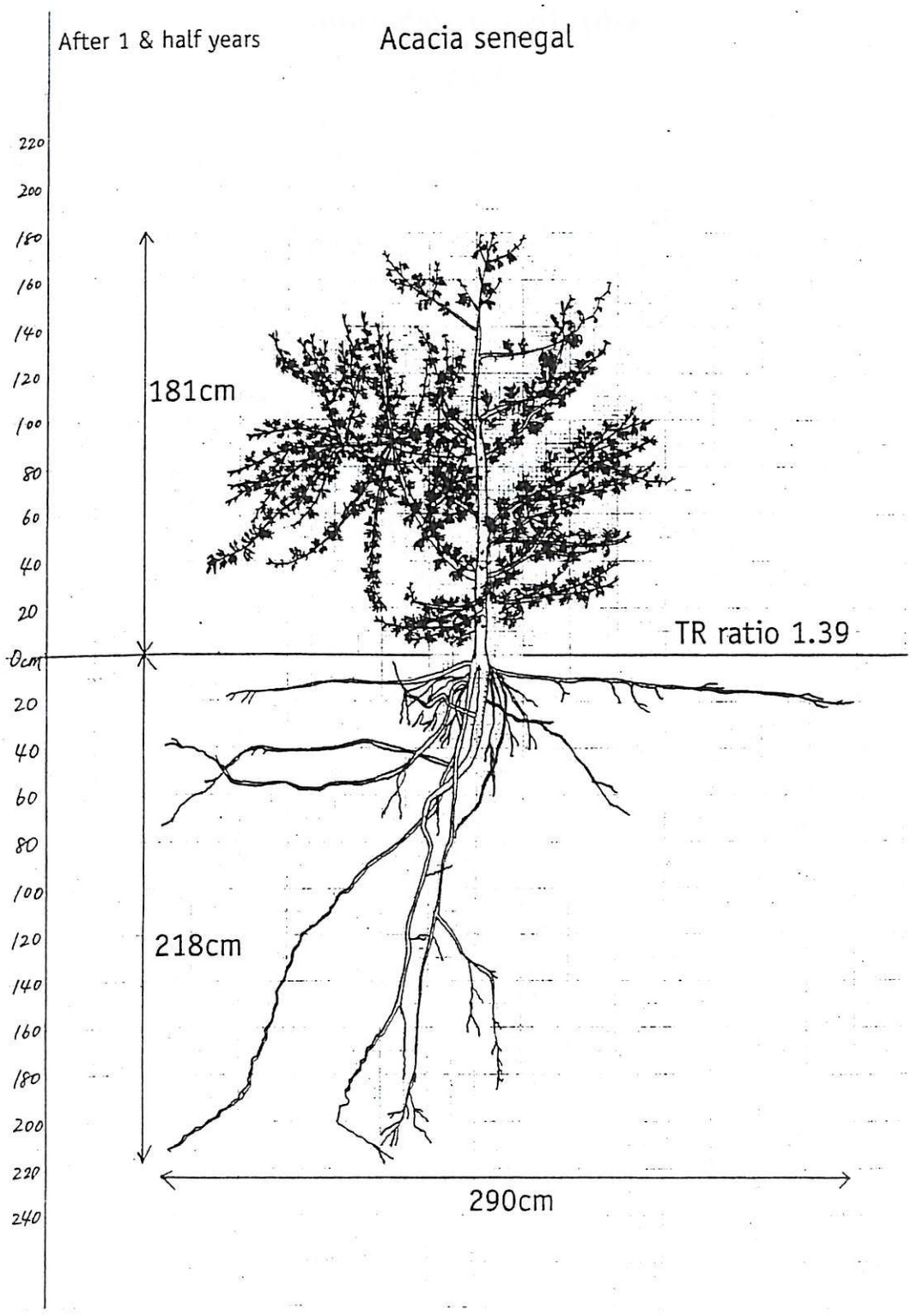


A-5) *Acacia senegal*

Acacia senegal

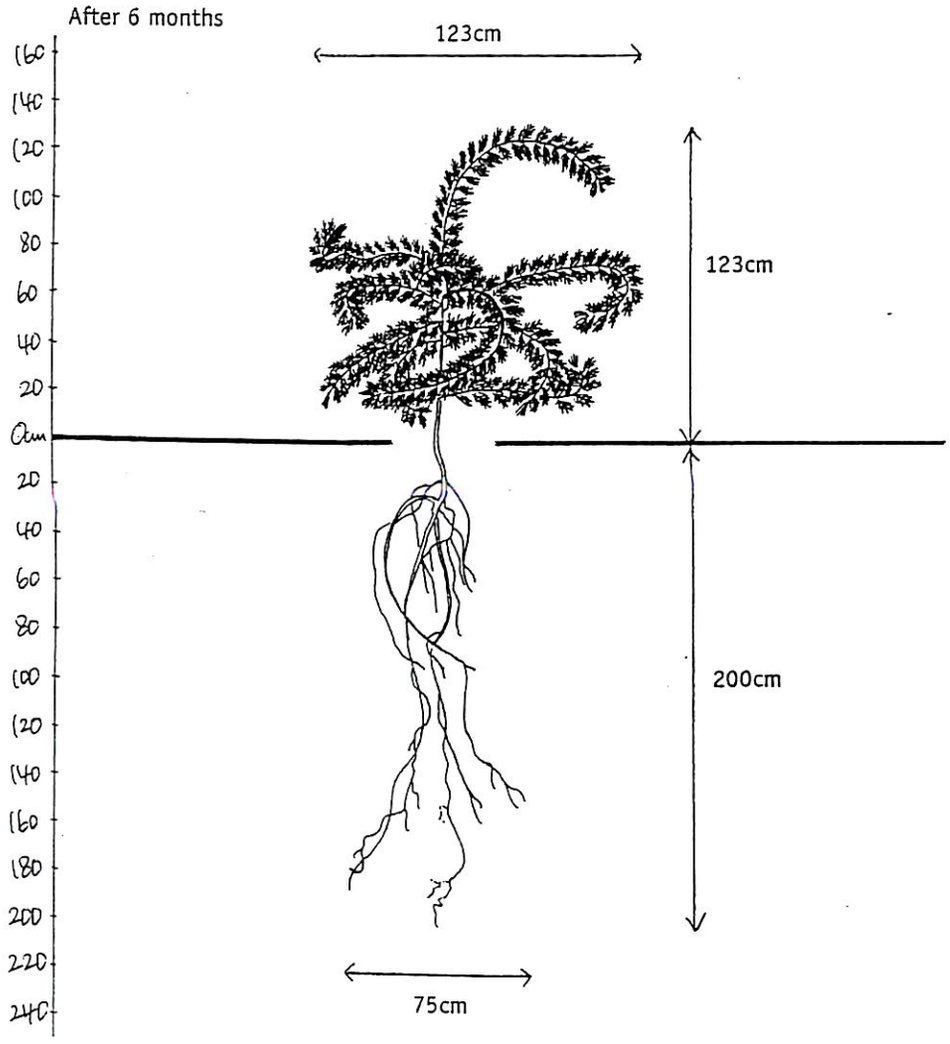


A-5) *Acacia senegal*

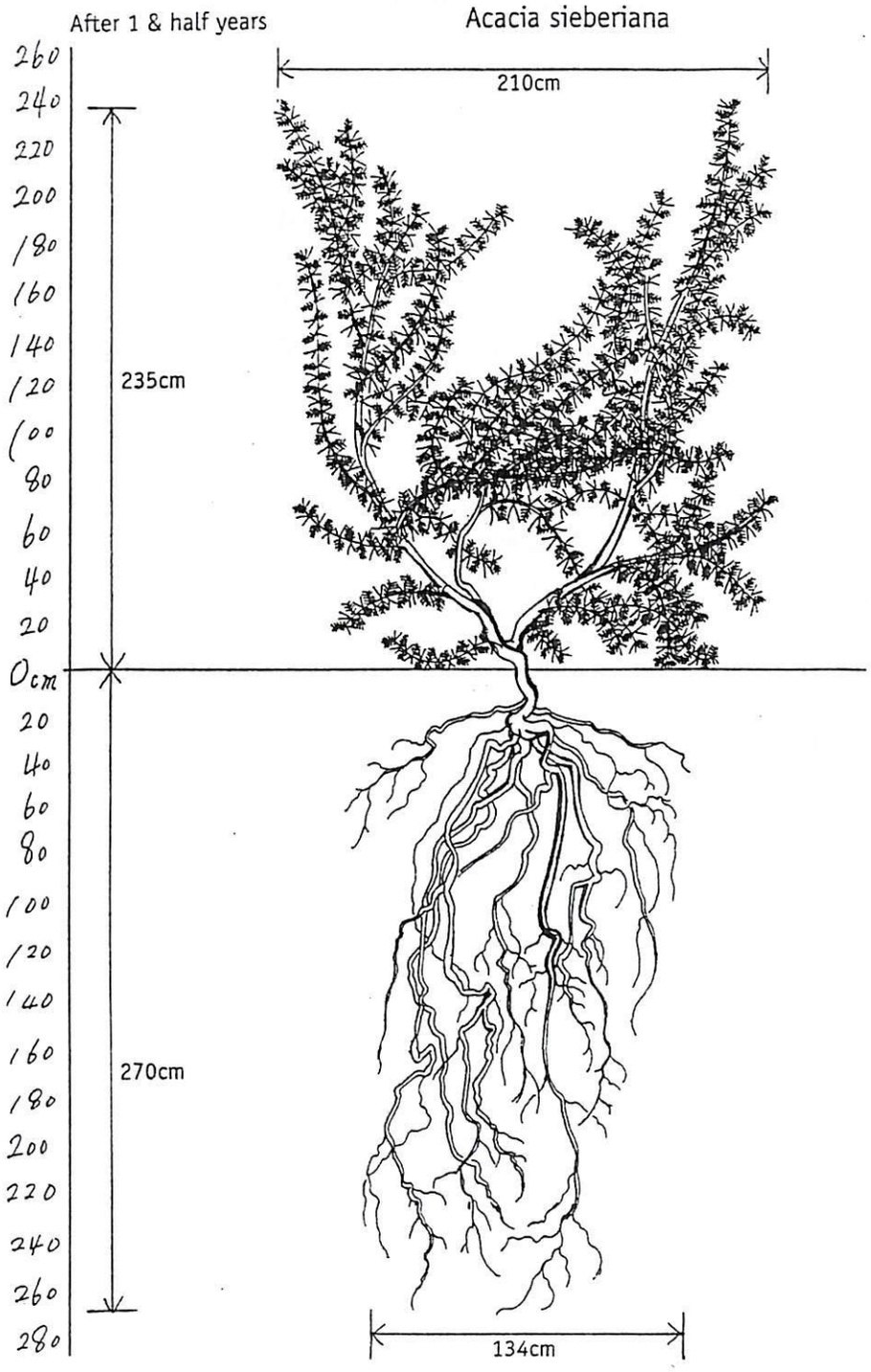


A-6) *Acacia sieberiana*

Acacia sieberiana

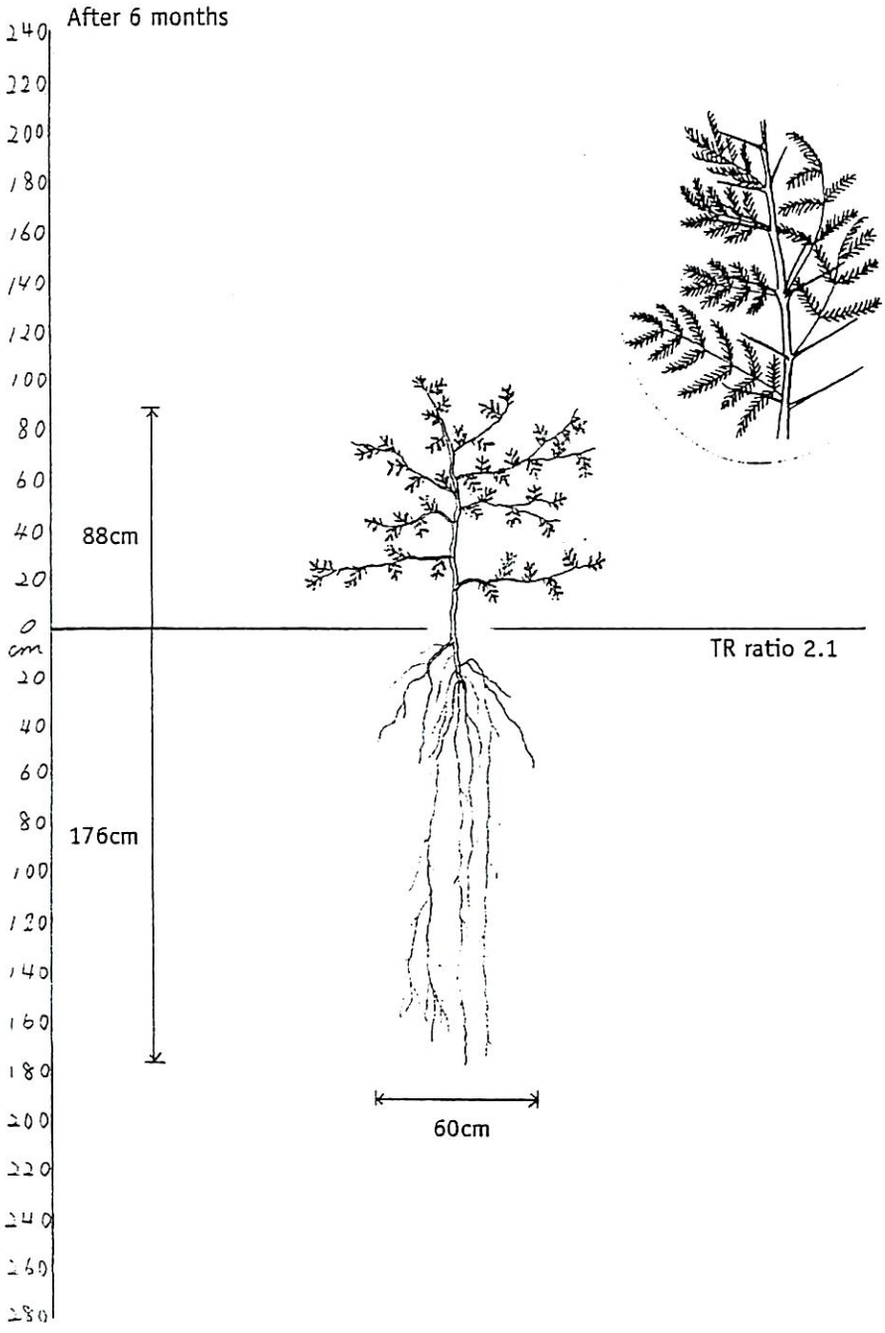


A-6) *Acacia sieberiana*

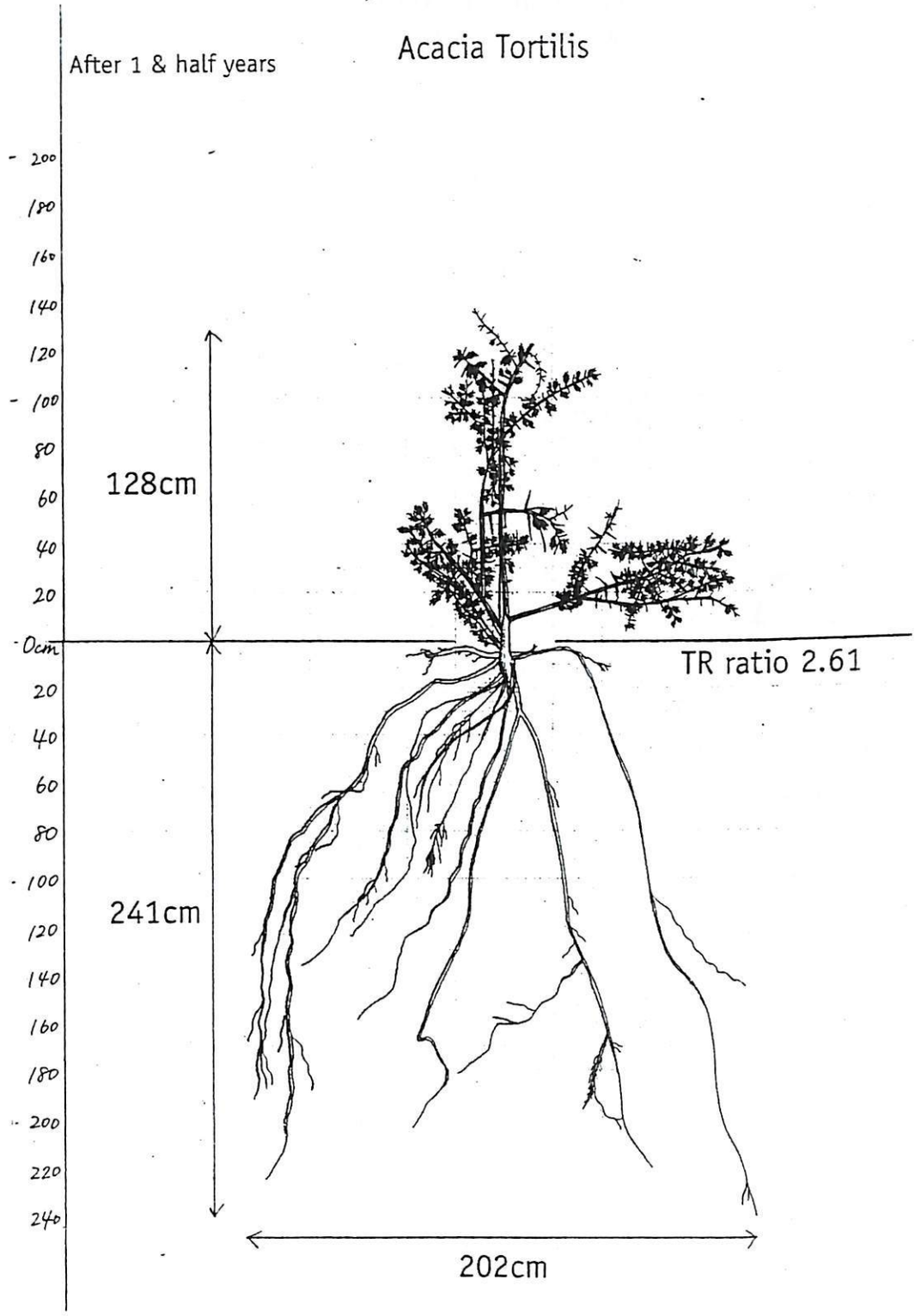


A-7) *Acacia tortillis*

Acacia tortillis

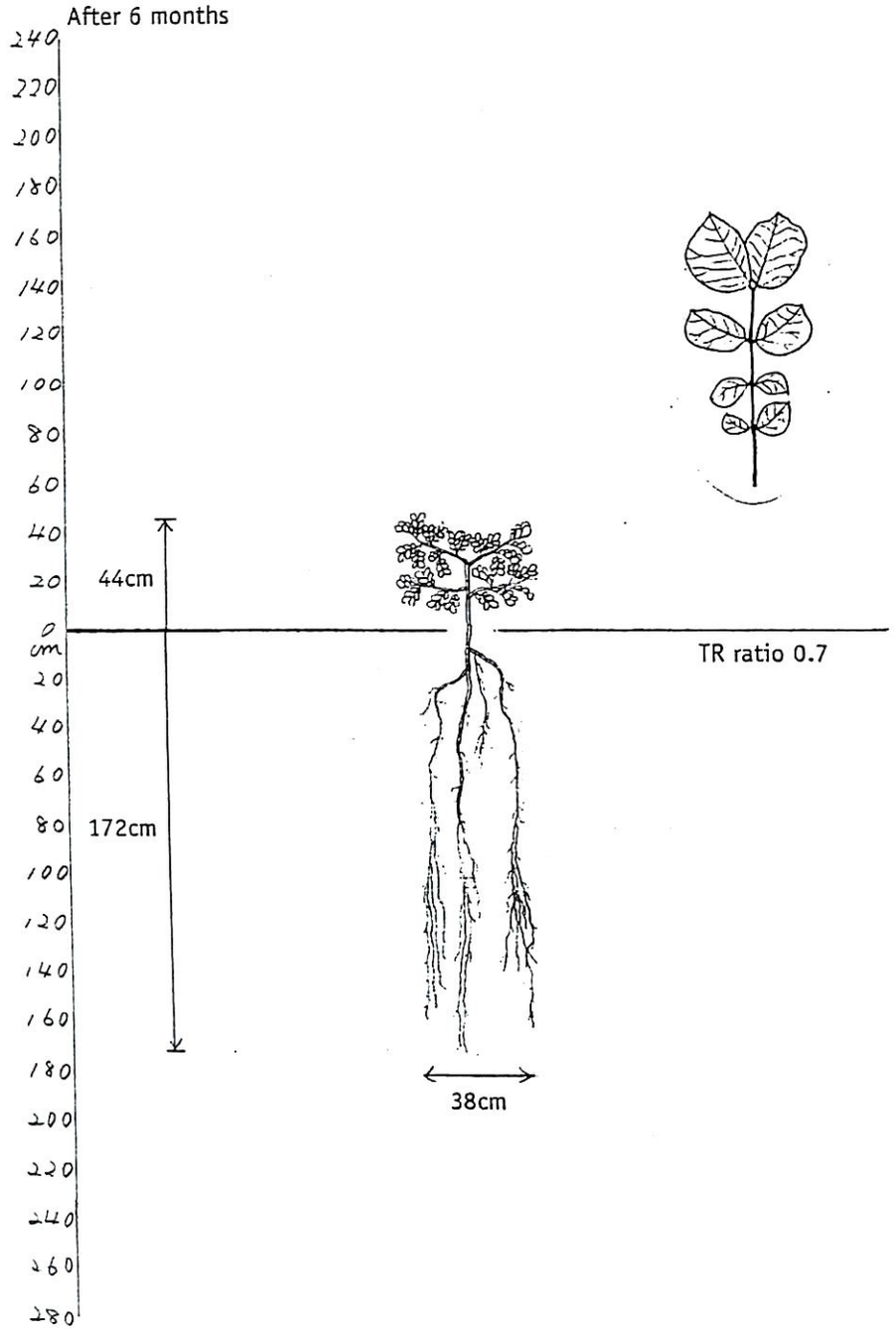


A-7) *Acacia tortillis*



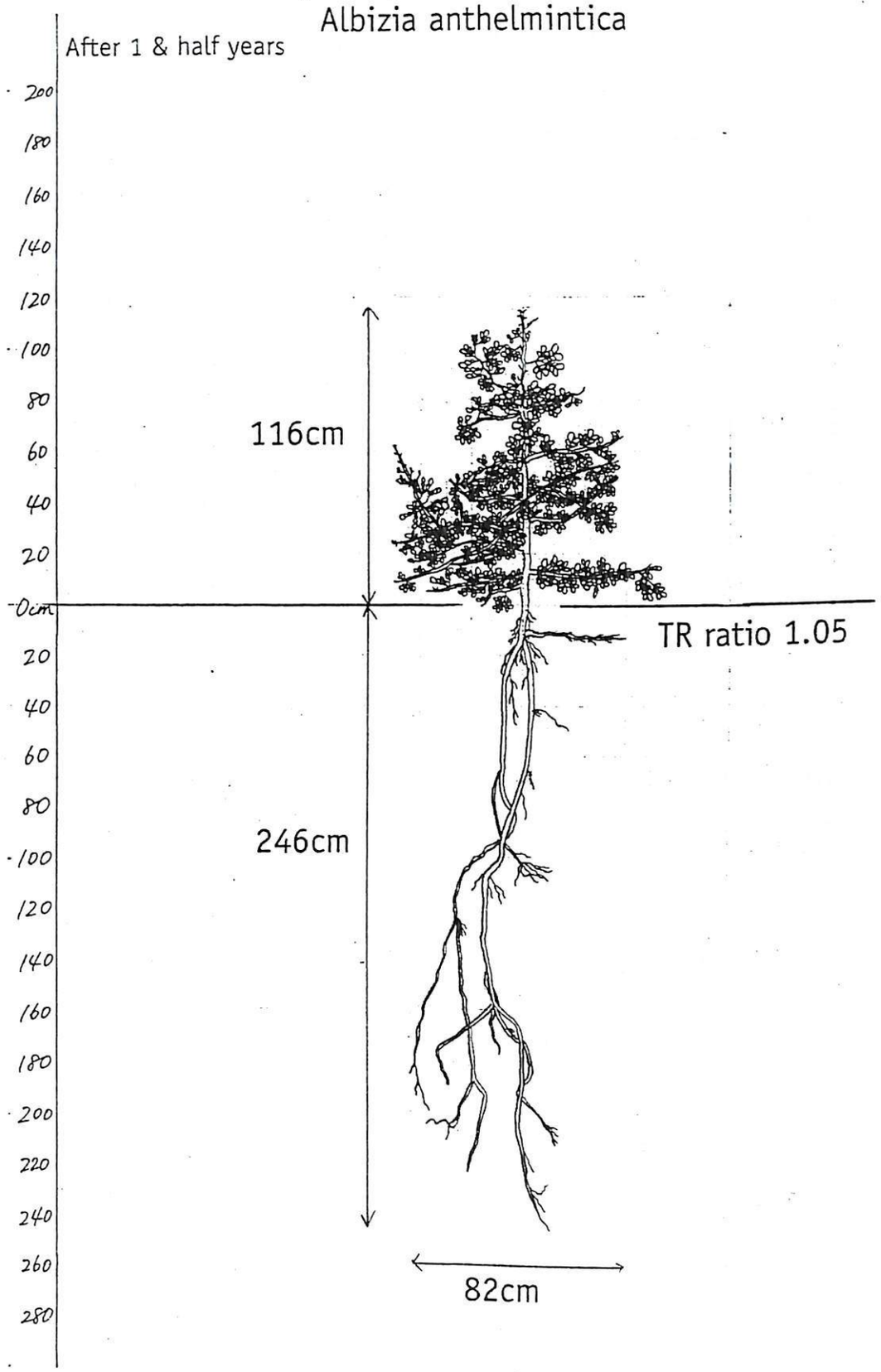
A-8) *Albizia anthelmintica*

Albizia anthelmintica



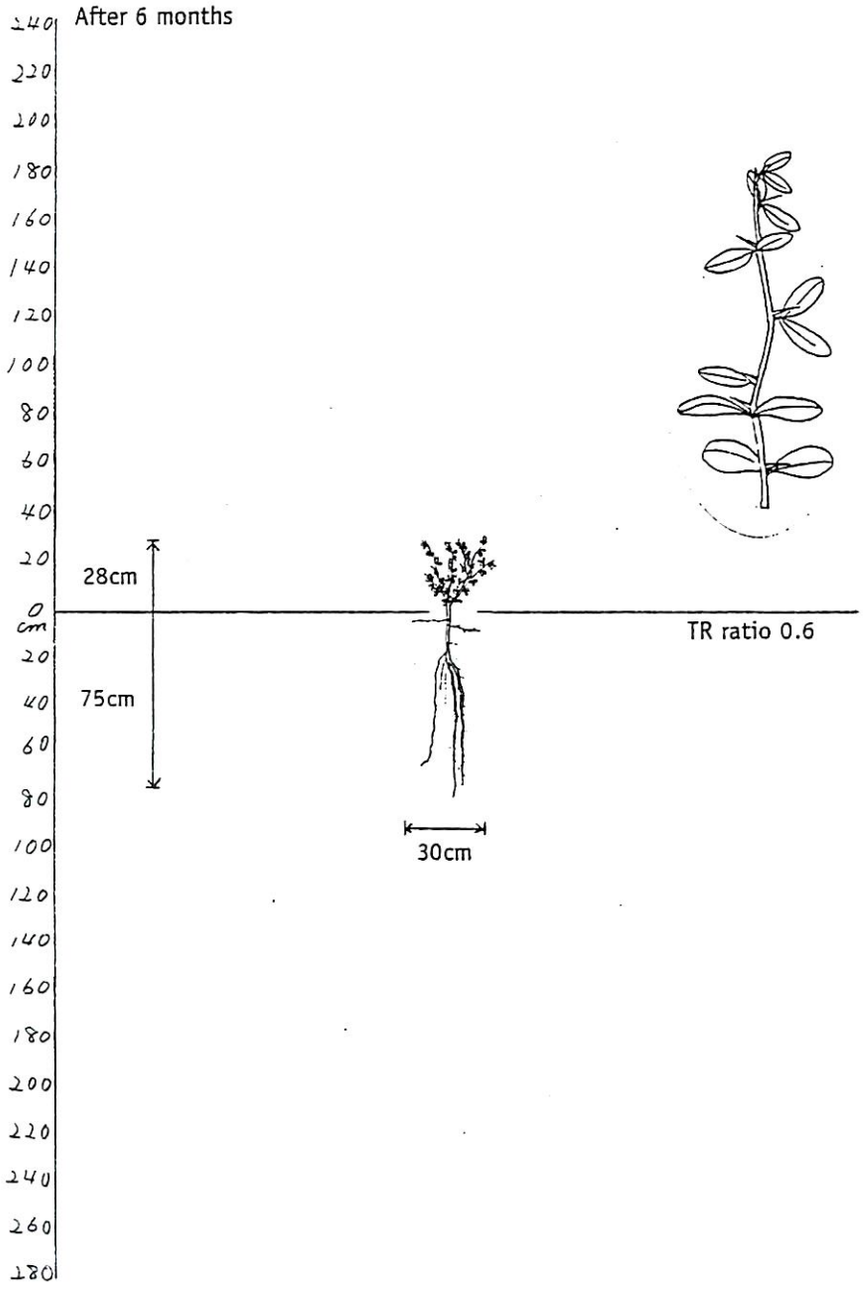
A-8) *Albizia anthelmintica*

Albizia anthelmintica



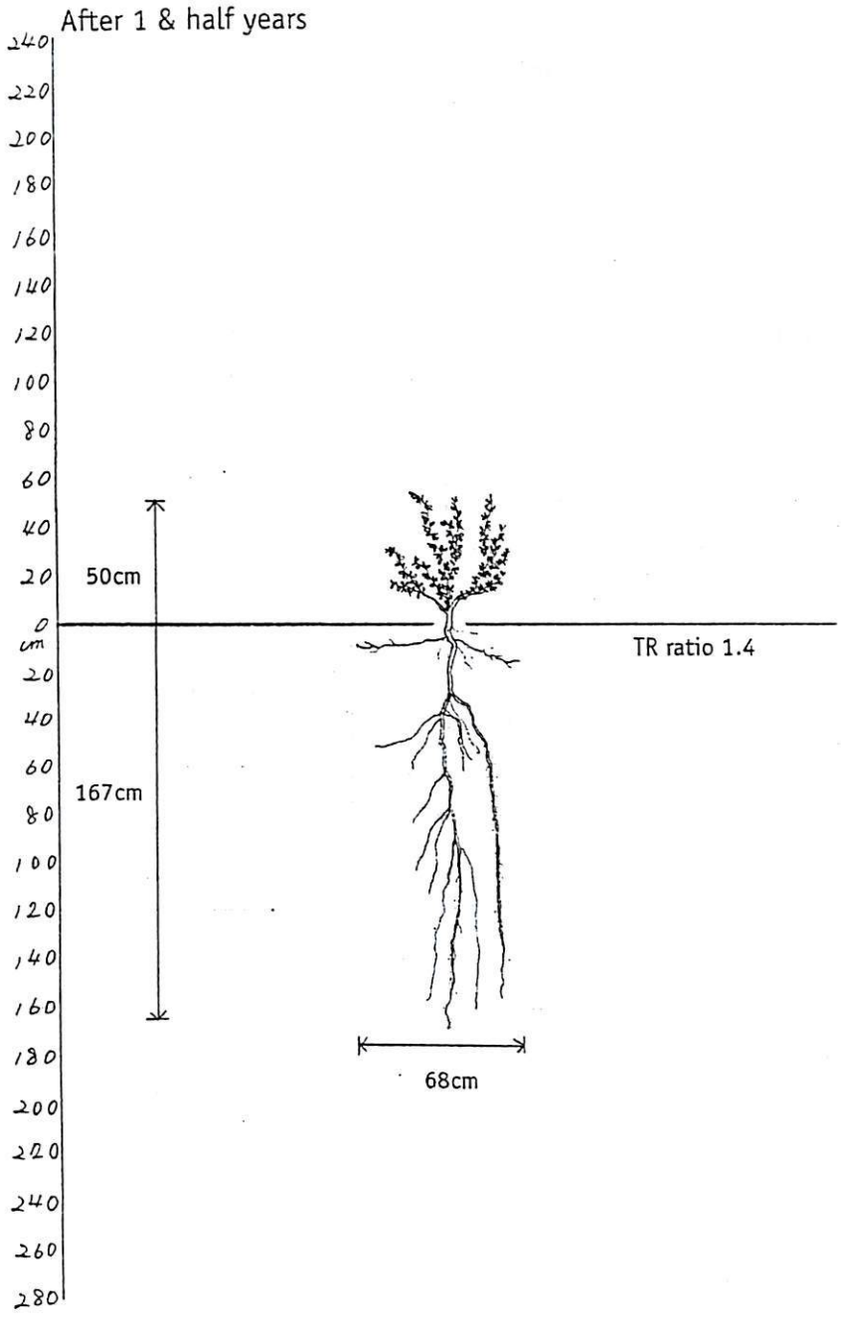
A-9) Balanites aegyptiaca

Balanites aegyptiaca



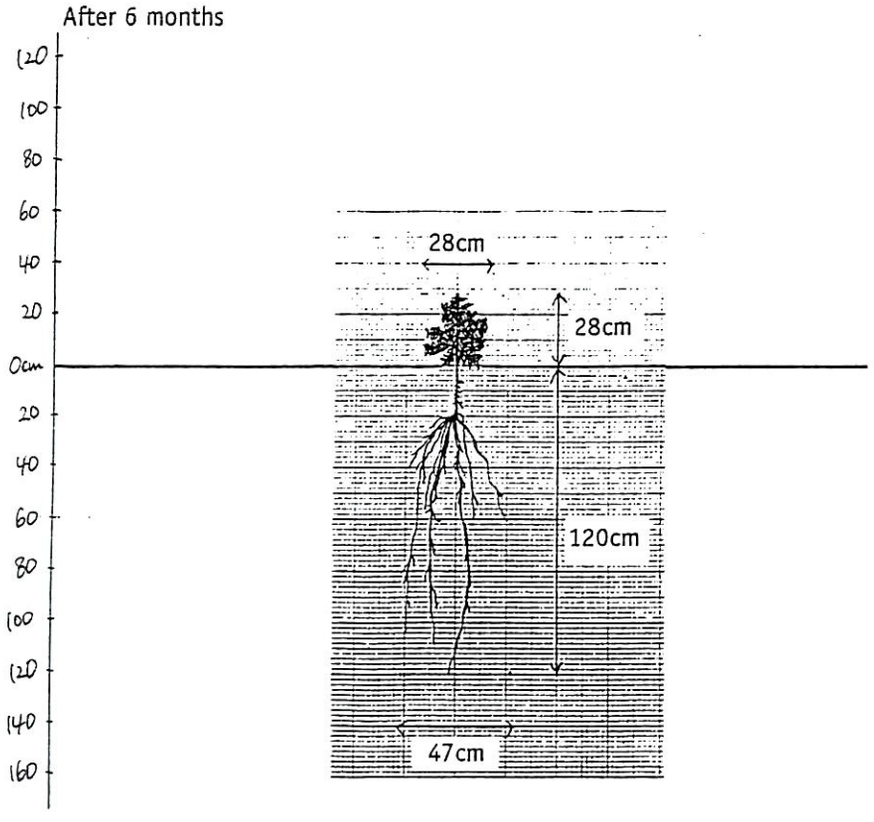
A-9) *Balanites aegyptiaca*

Balanites aegyptiaca



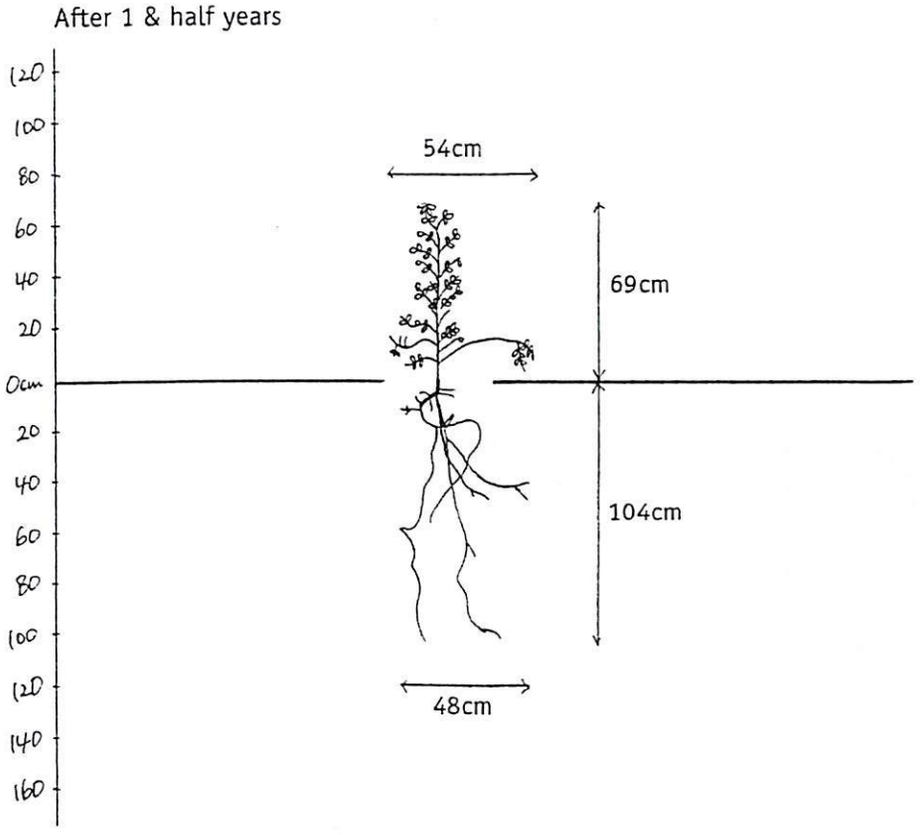
A-10) *Berchemia discolor*

Berchemia discolor



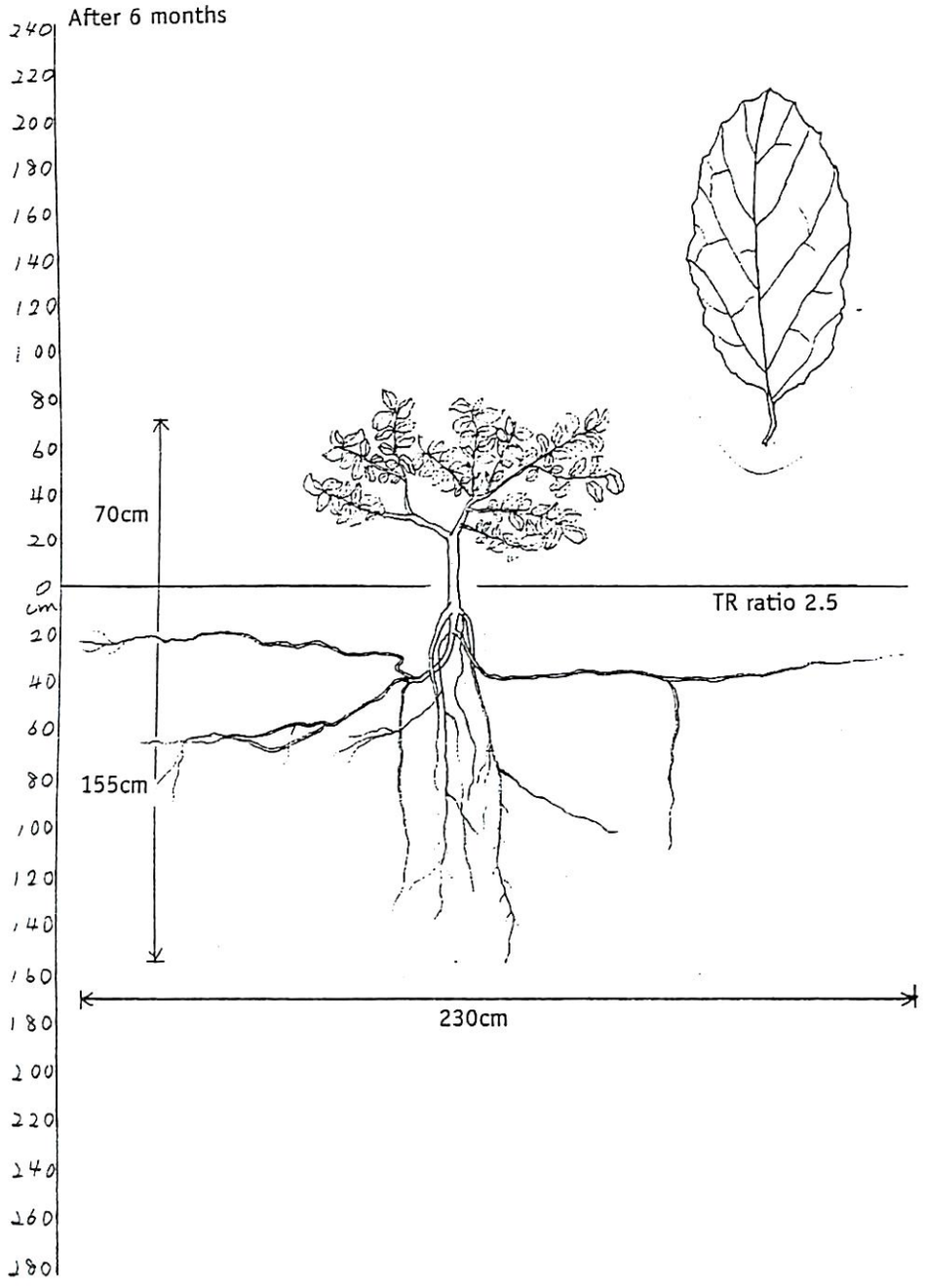
A-10) *Berchemia discolor*

Berchemia discolor

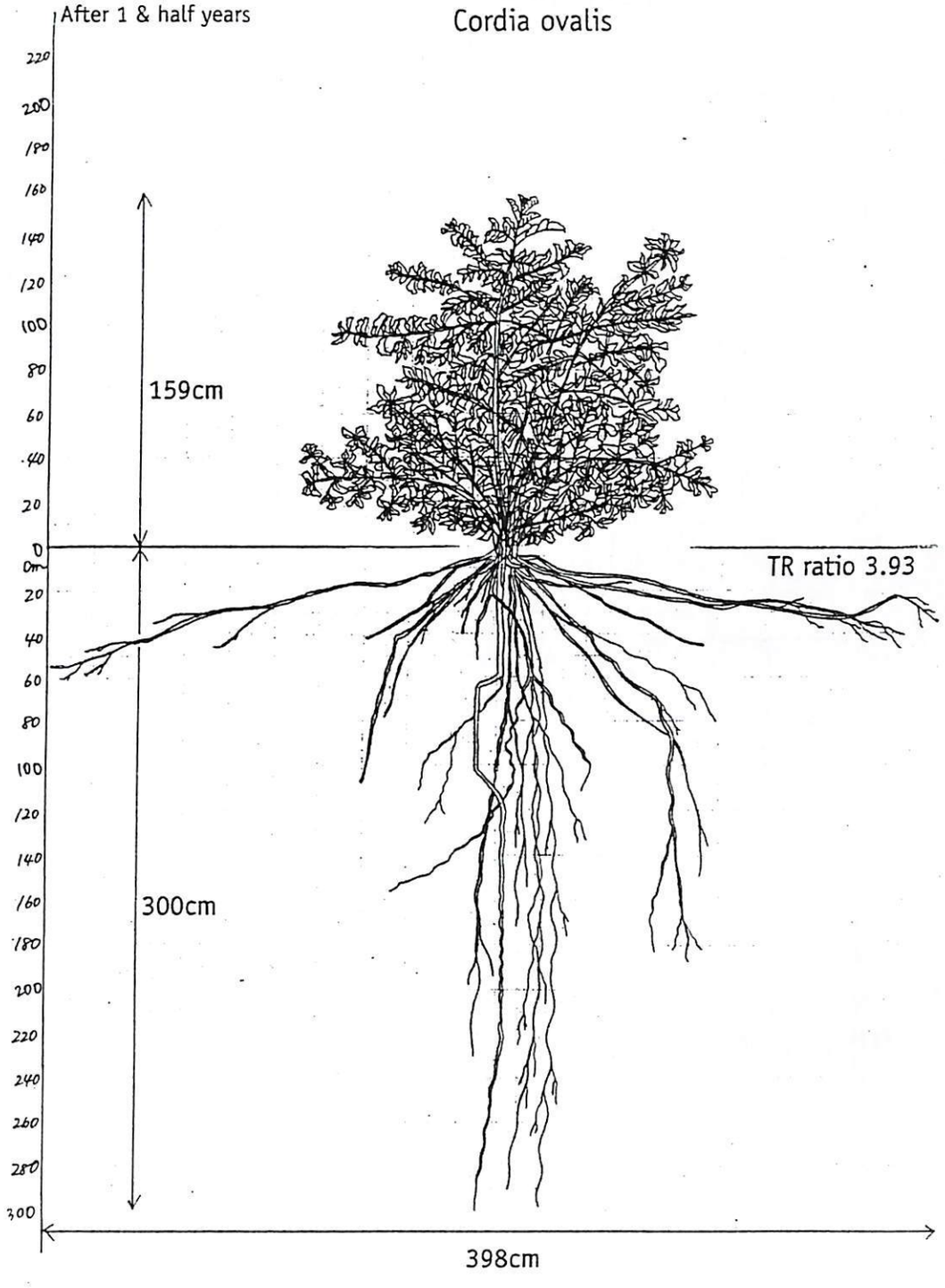


A-11) *Coridia ovalis*

Coridia ovalis

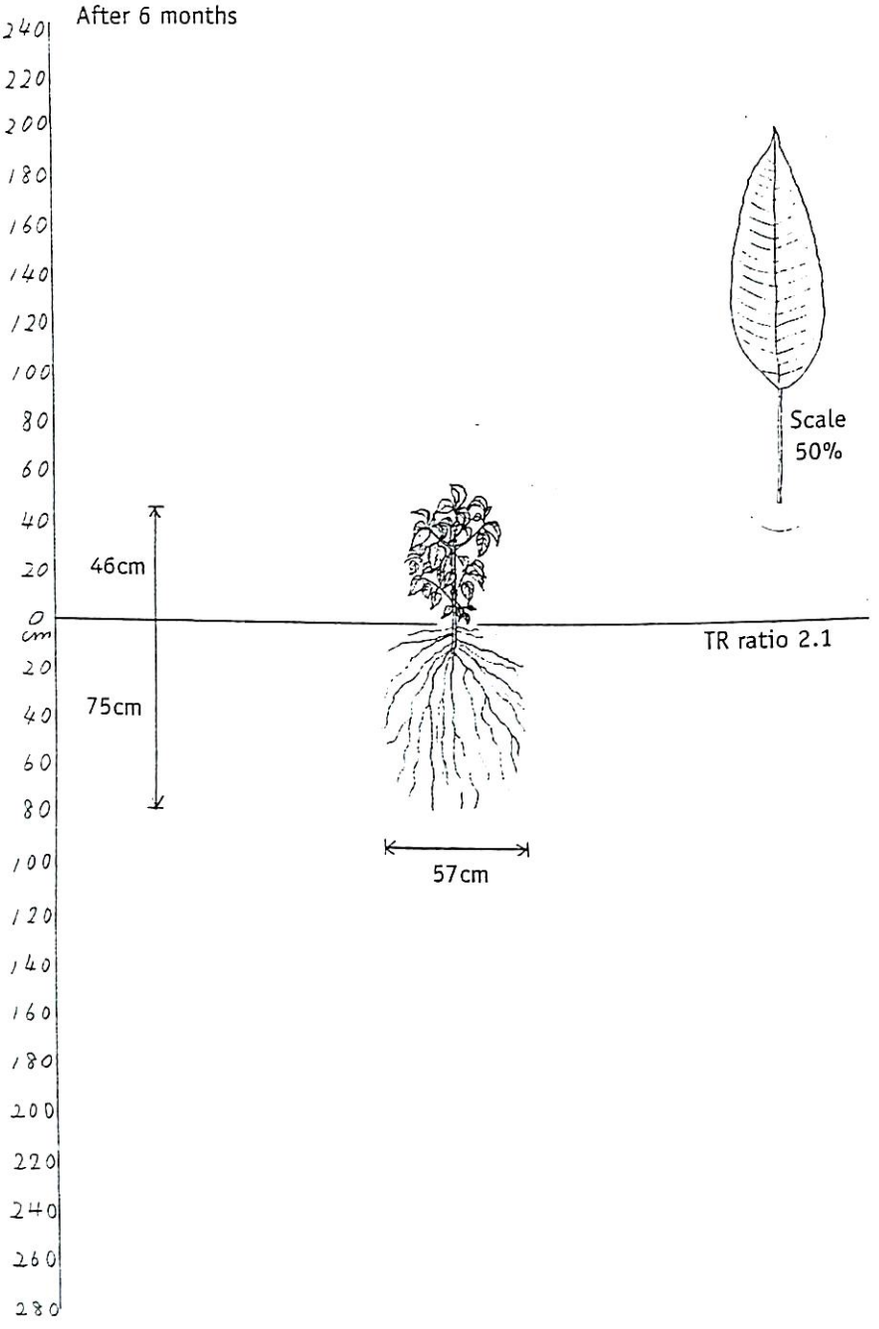


A-11) *Cordia ovalis*



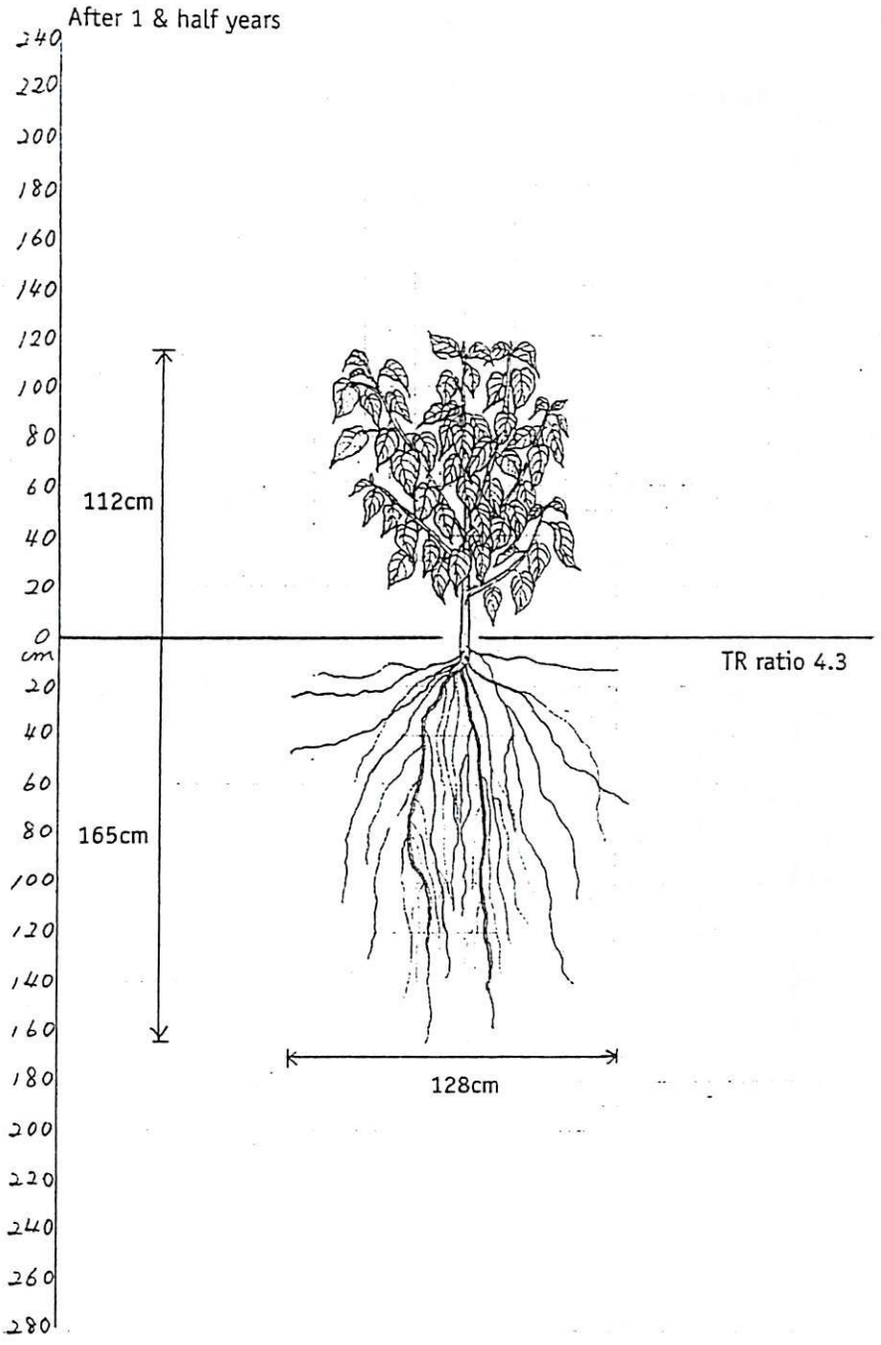
A-12) *Croton megalocarpus*

Croton megalocarpus

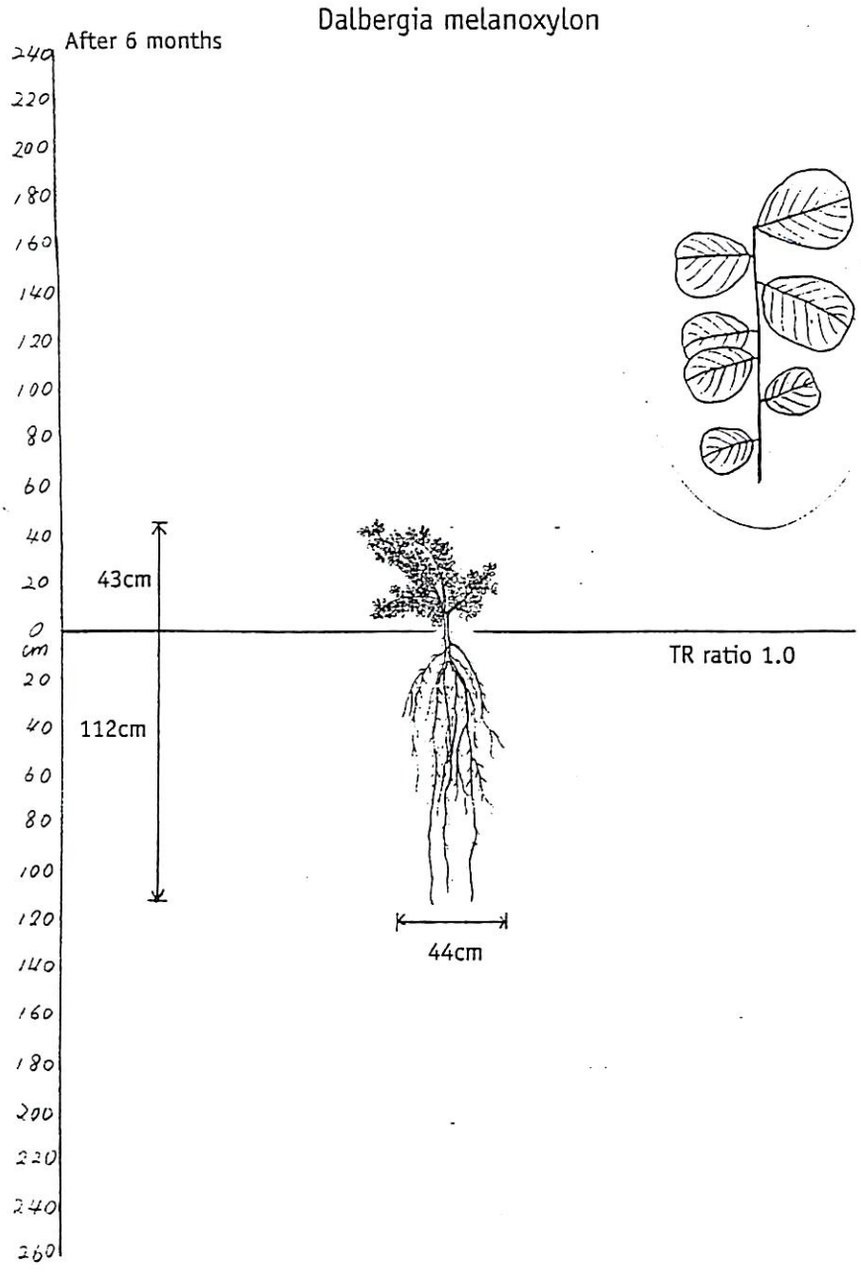


A-12) *Croton megalocarpus*

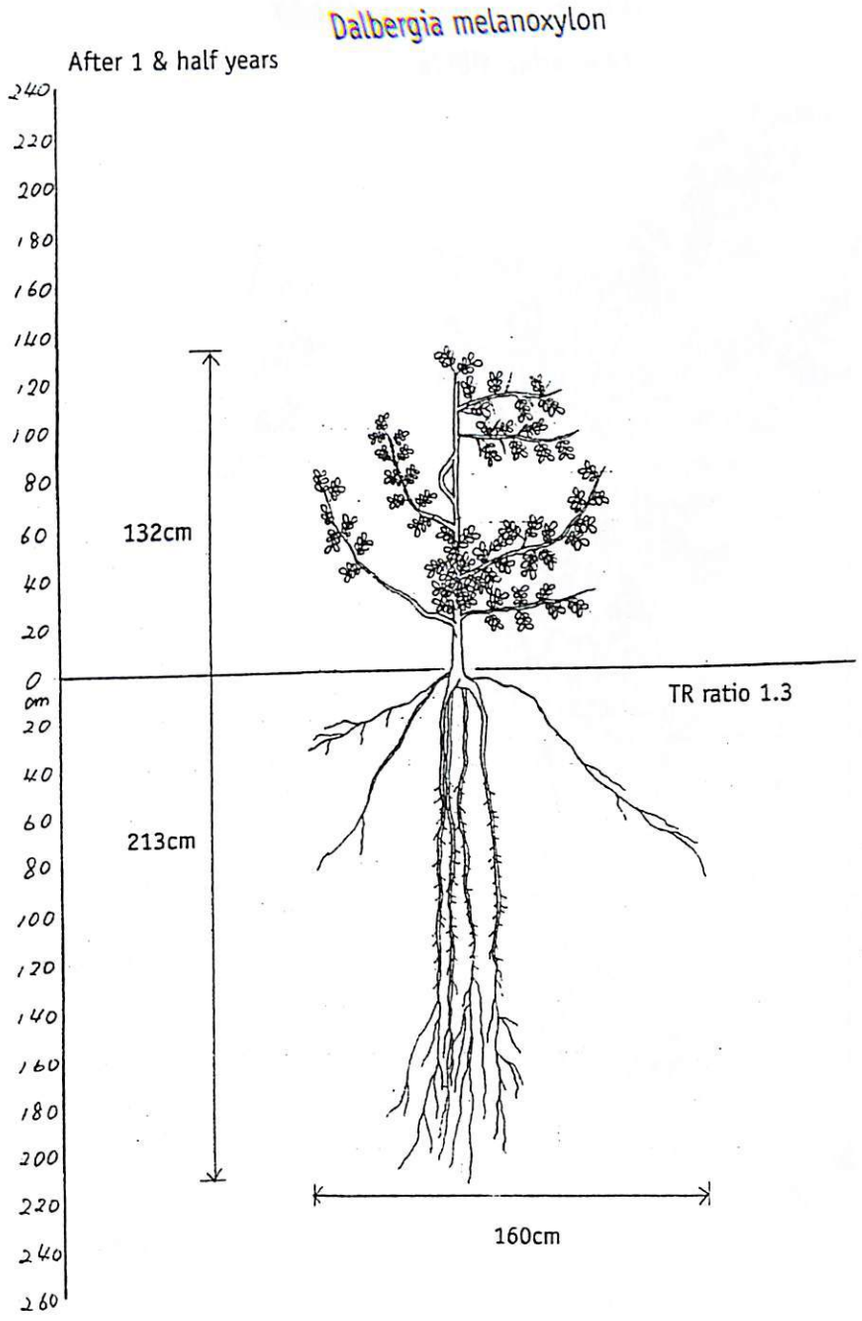
Croton megalocarpus



A-13) *Dalbergia melanoxylon*

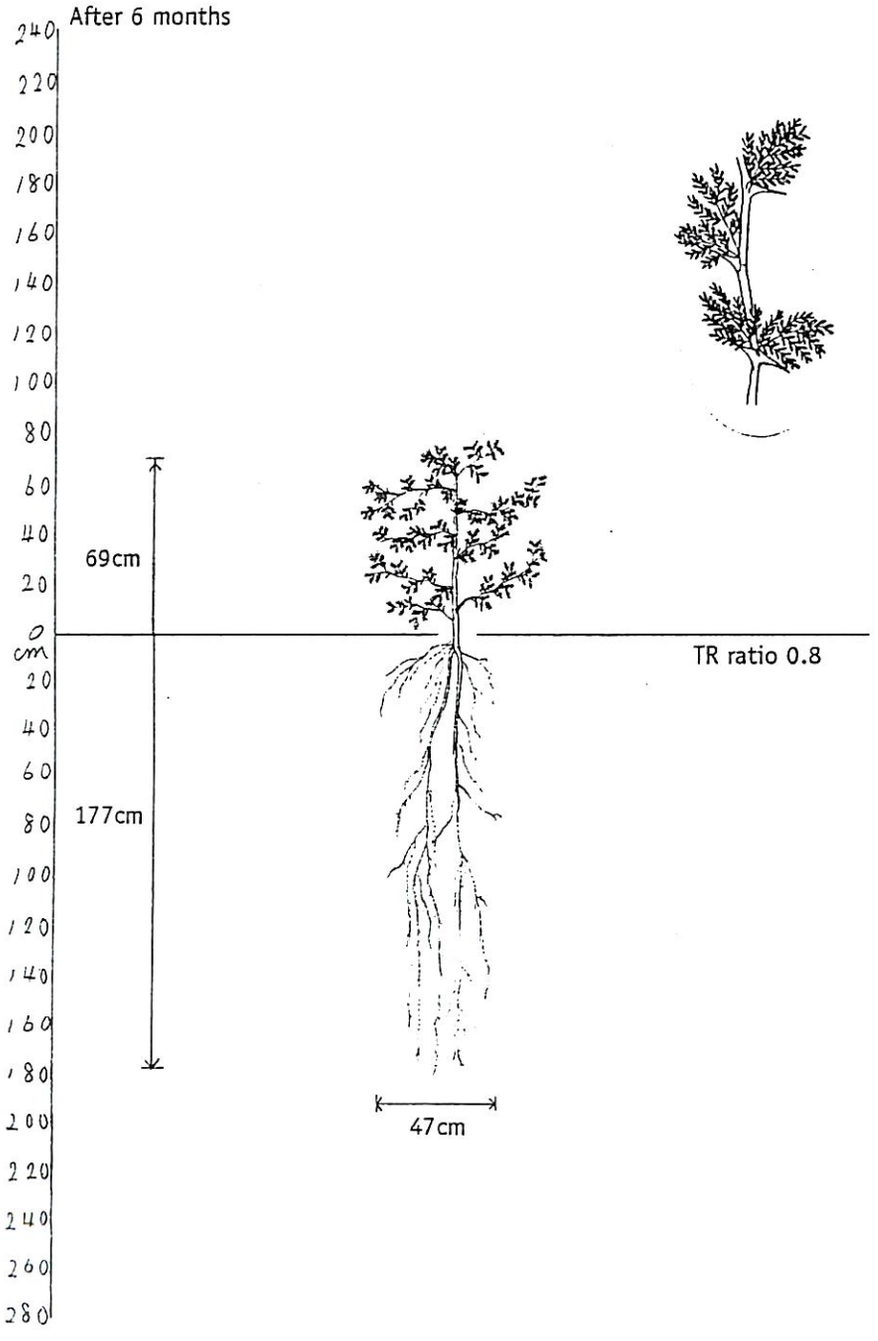


A-13) Dalbergia melanoxylon

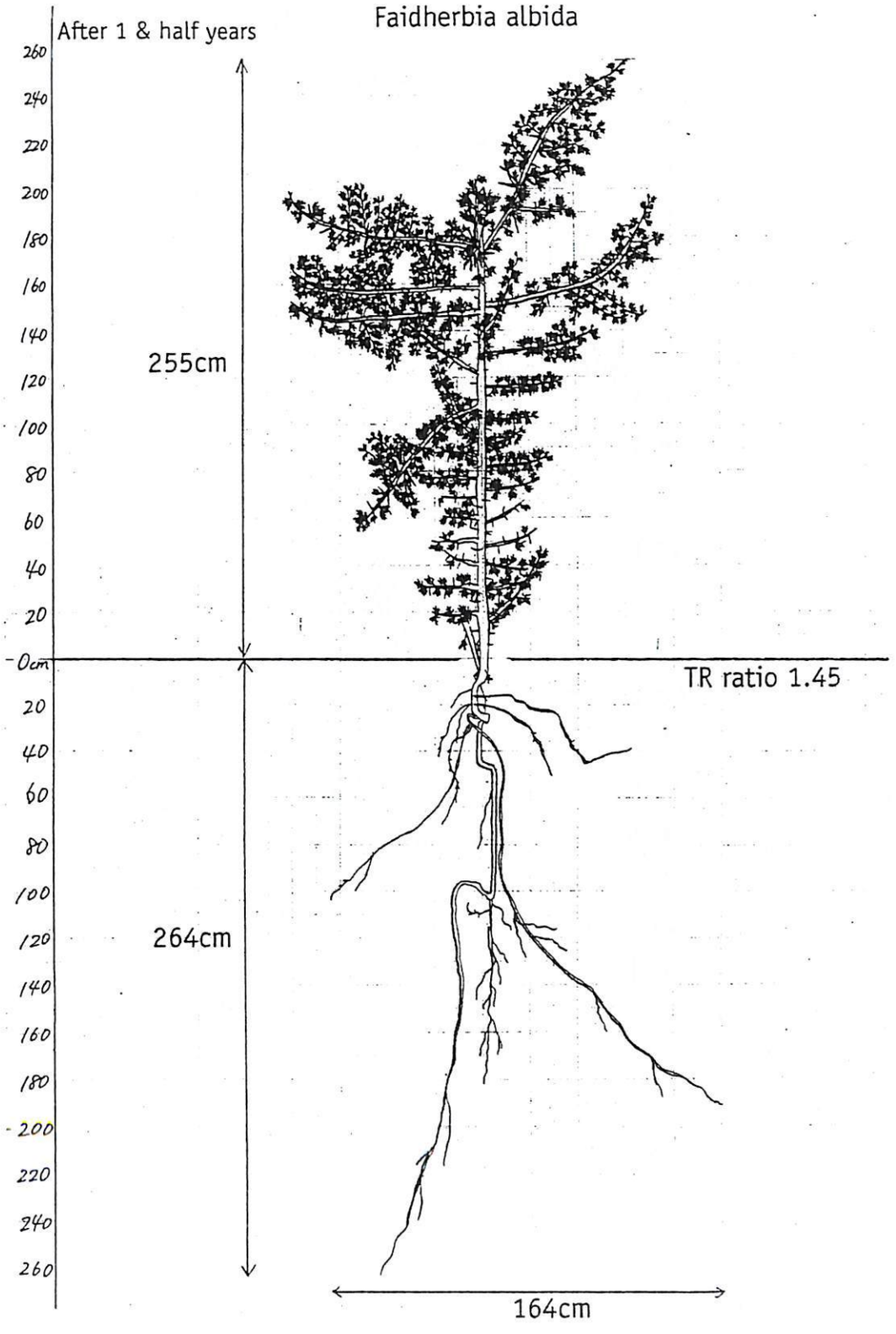


A-14) *Faidherbia albida*

Faidherbia albida

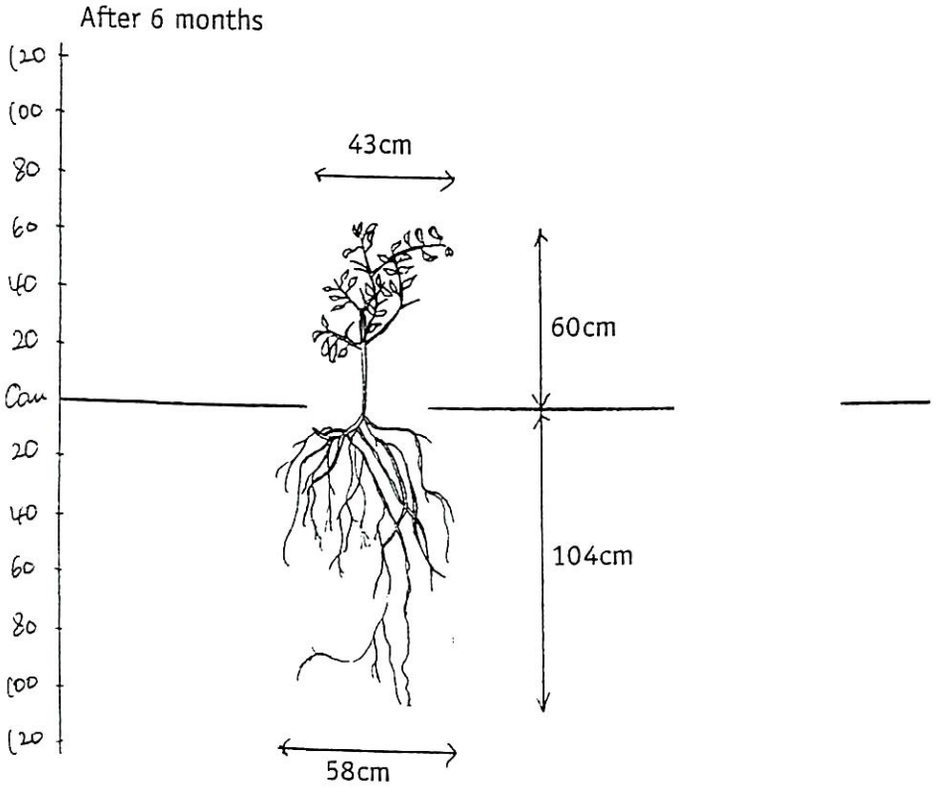


A-14) *Faidherbia albida*



A-15) *Grewia aricantha*

Grewia aricantha

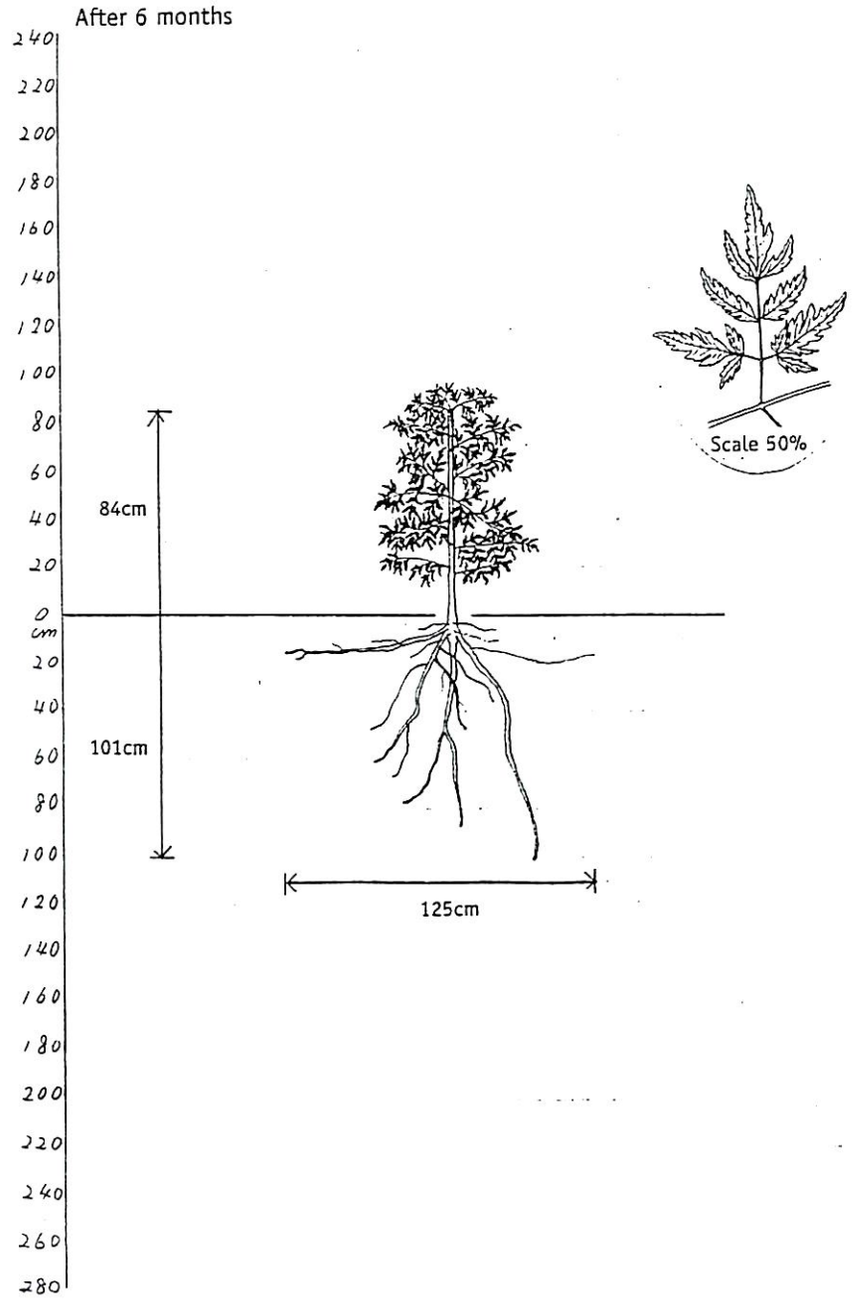


A-15) *Grewia aricantha*

- Data for 1 and half year is not available. -

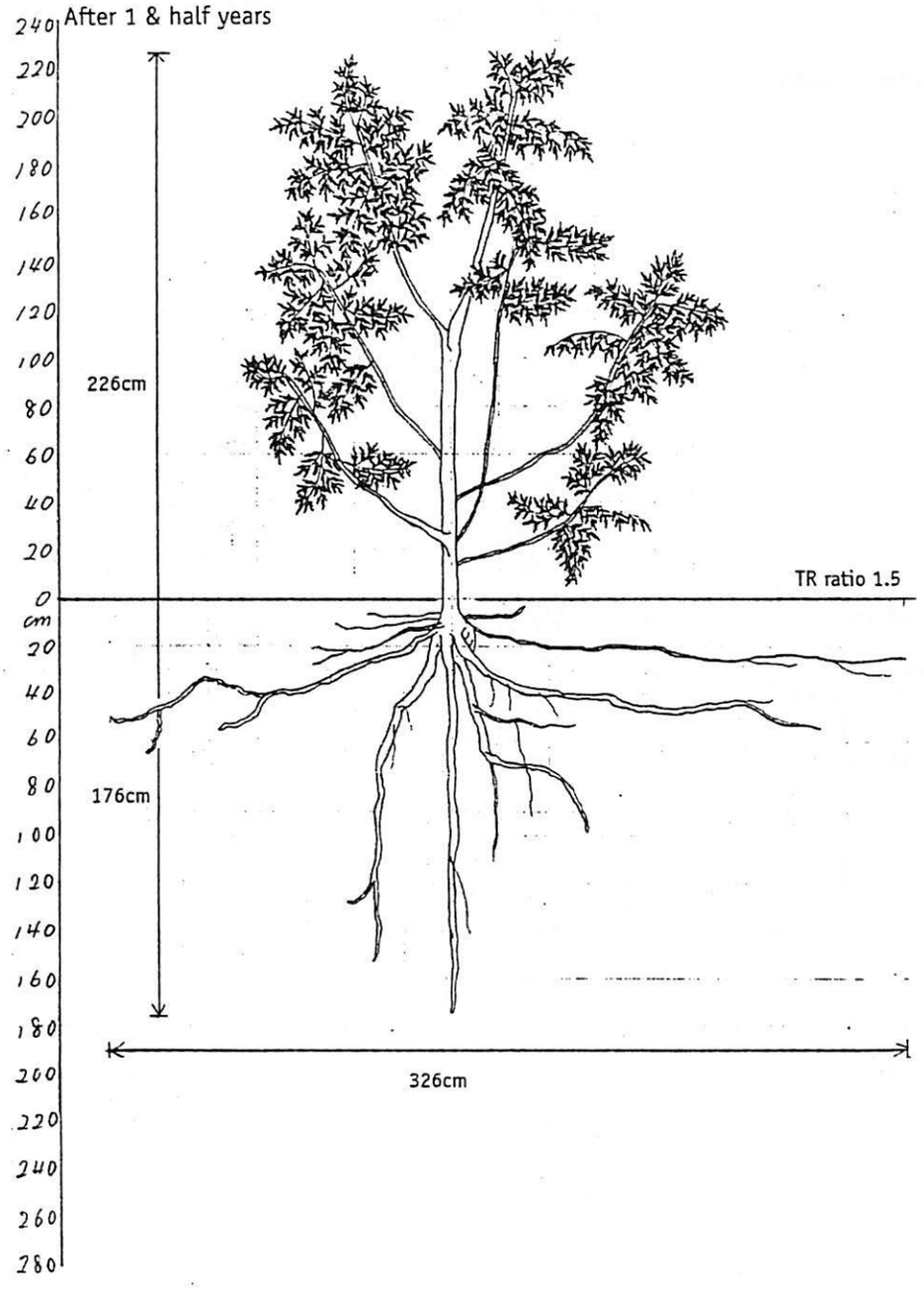
A-16) *Melia volkensii*

Melia volkensii



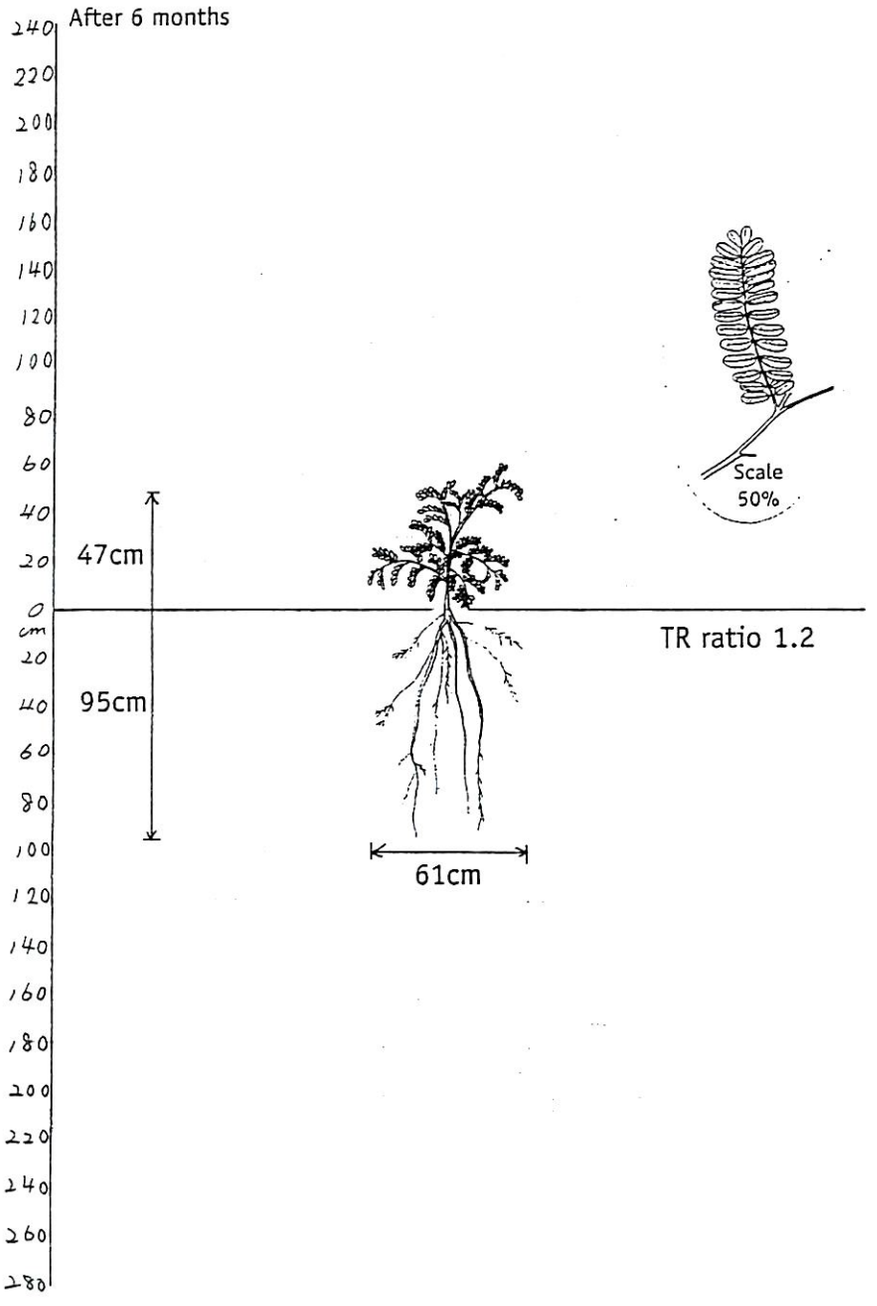
A-16) *Melia volkensii*

Melia volkensii



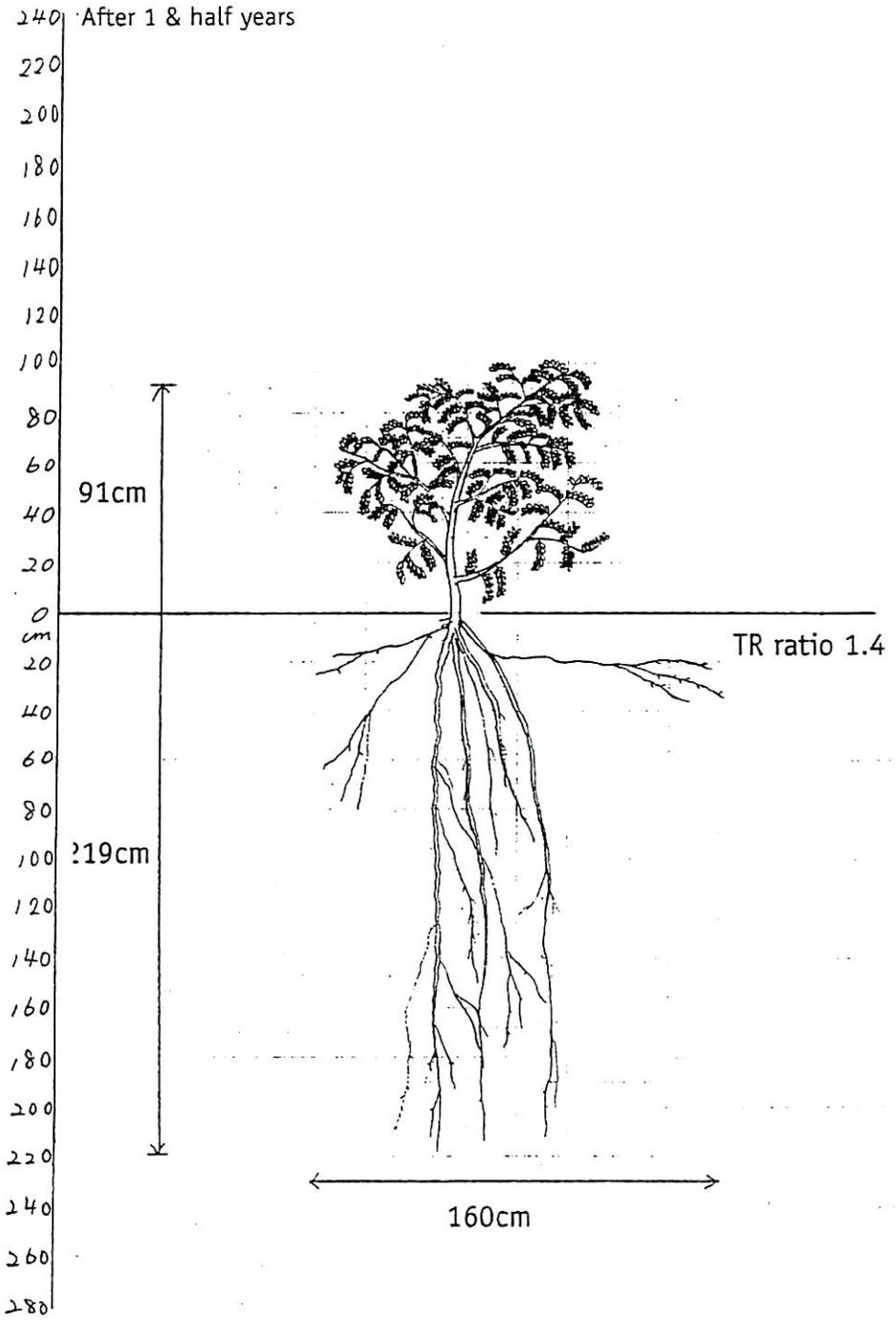
A-17) *Tamarindus indica*

Tamarindus indica



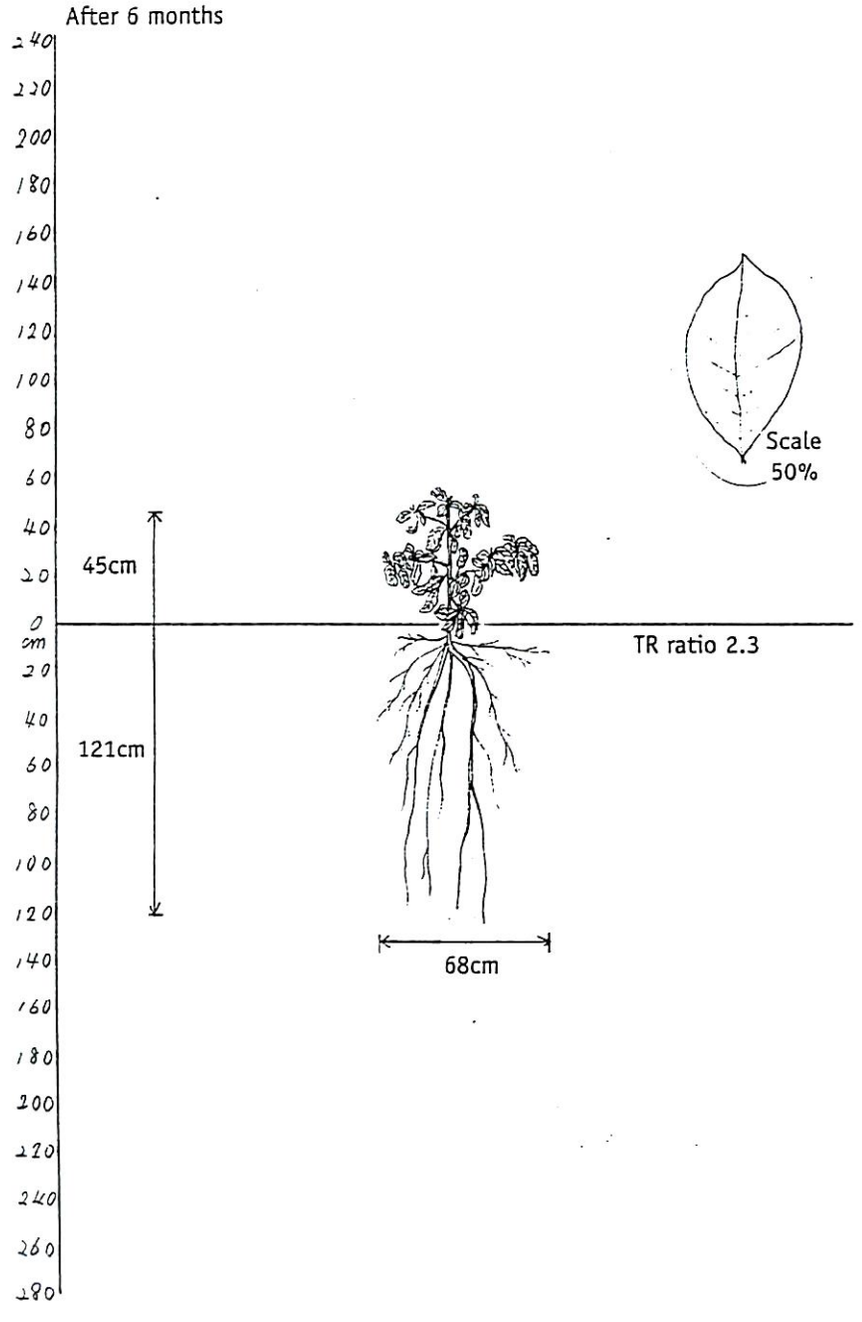
A-17) *Tamarindus indica*

Tamarindus indica



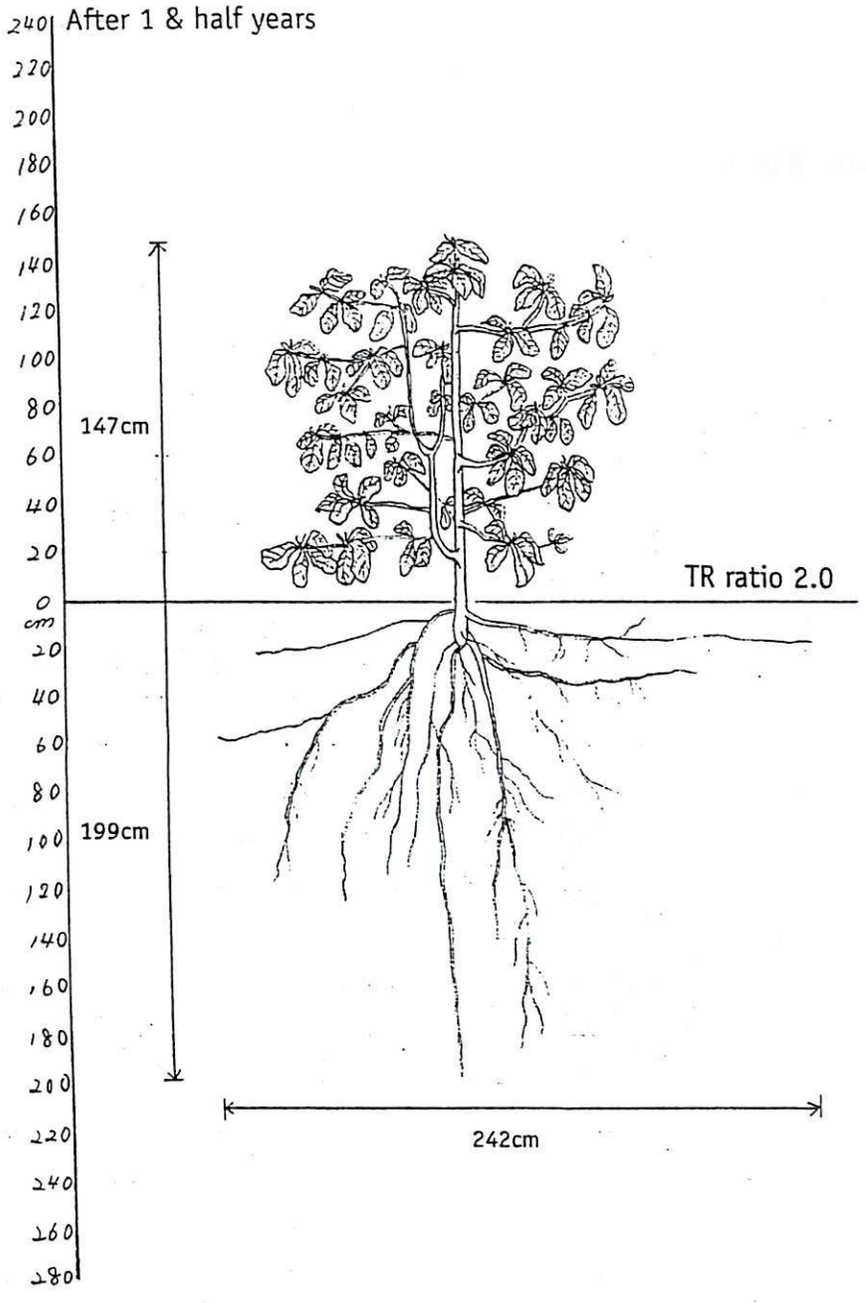
A-18) *Terminalia brownii*

Terminalia brownii



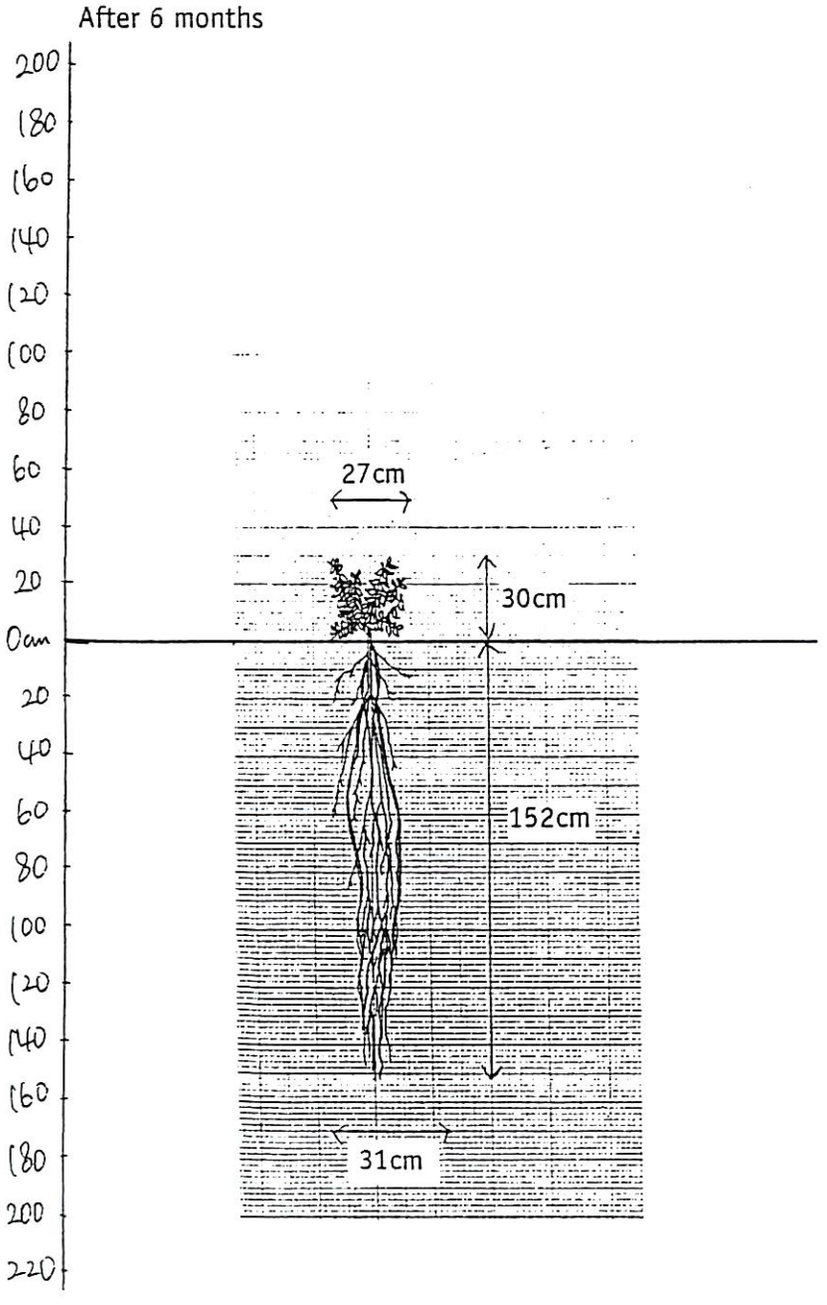
A-18) *Terminalia brownii*

Terminalia brownii



A-19) *Terminalia prunioides*

Terminalia prunioides

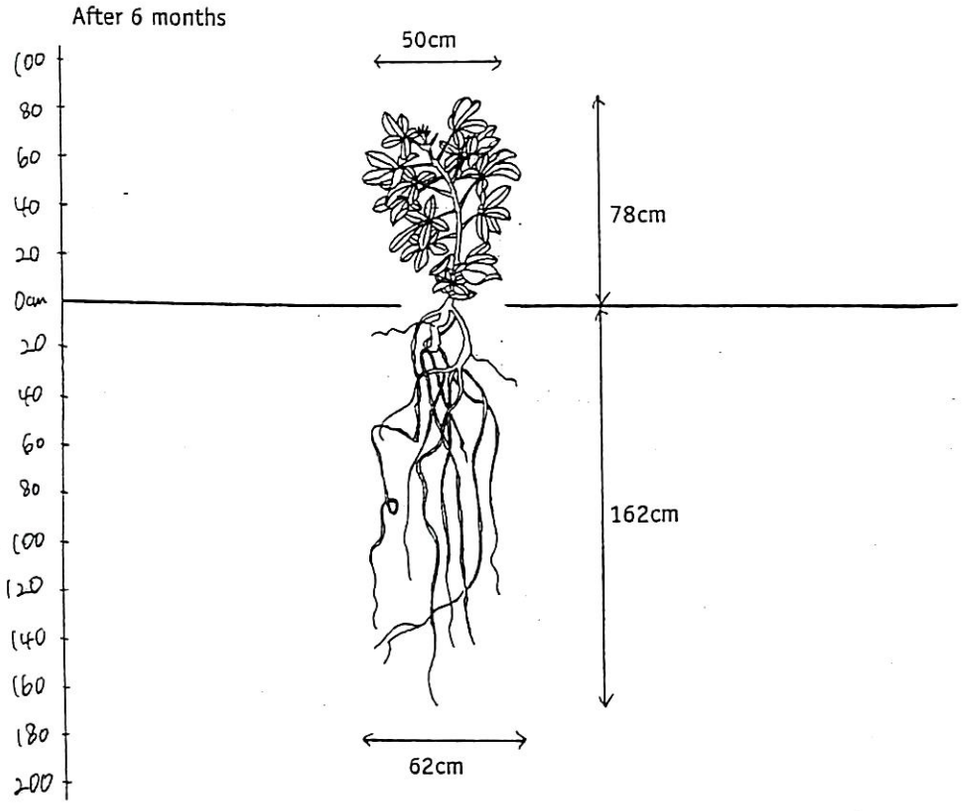


A-19) *Terminalia prunioides*

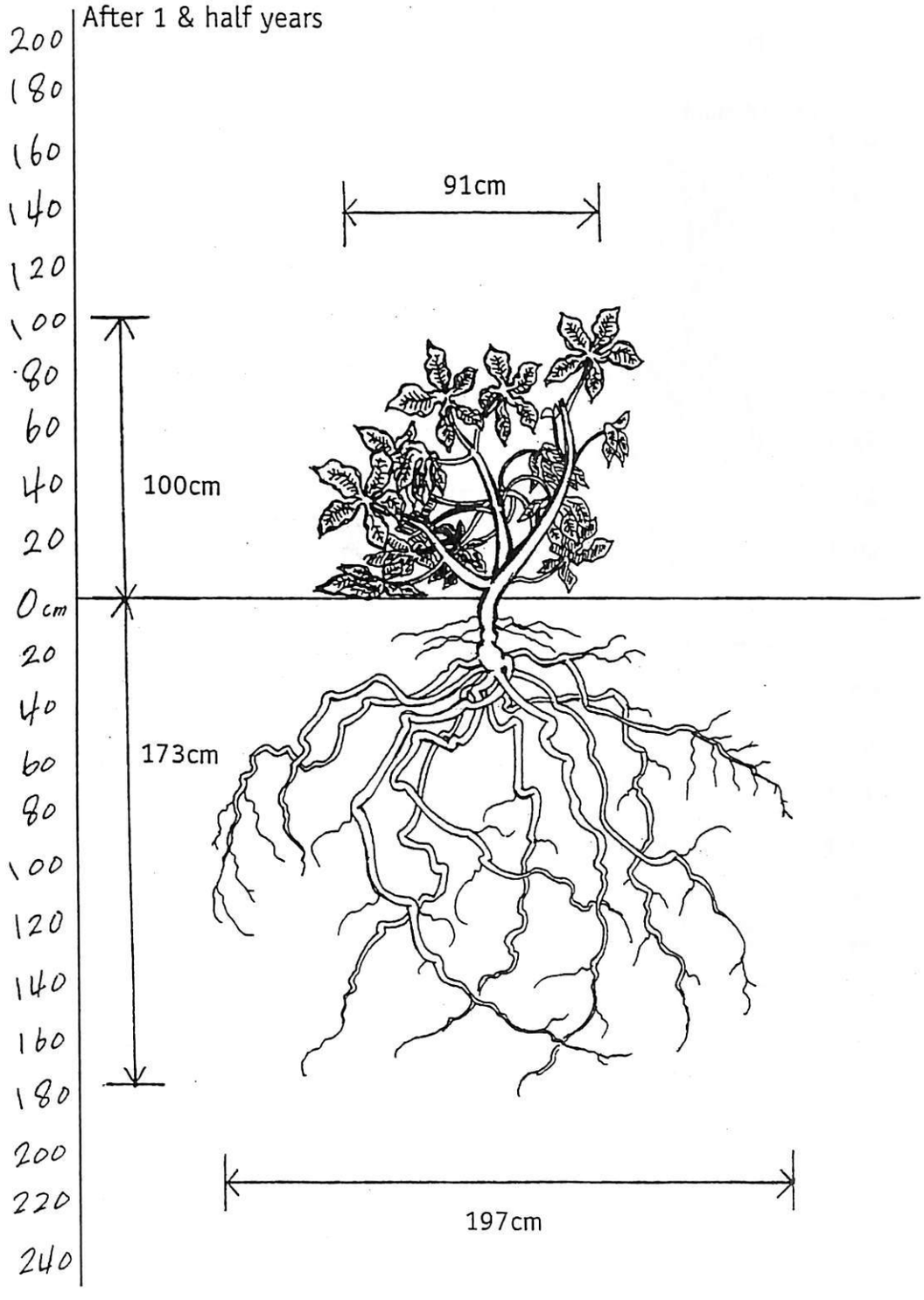
- Data for 1 and half year is not available. -

A-20) *Vitex doniana*

Vitex doniana

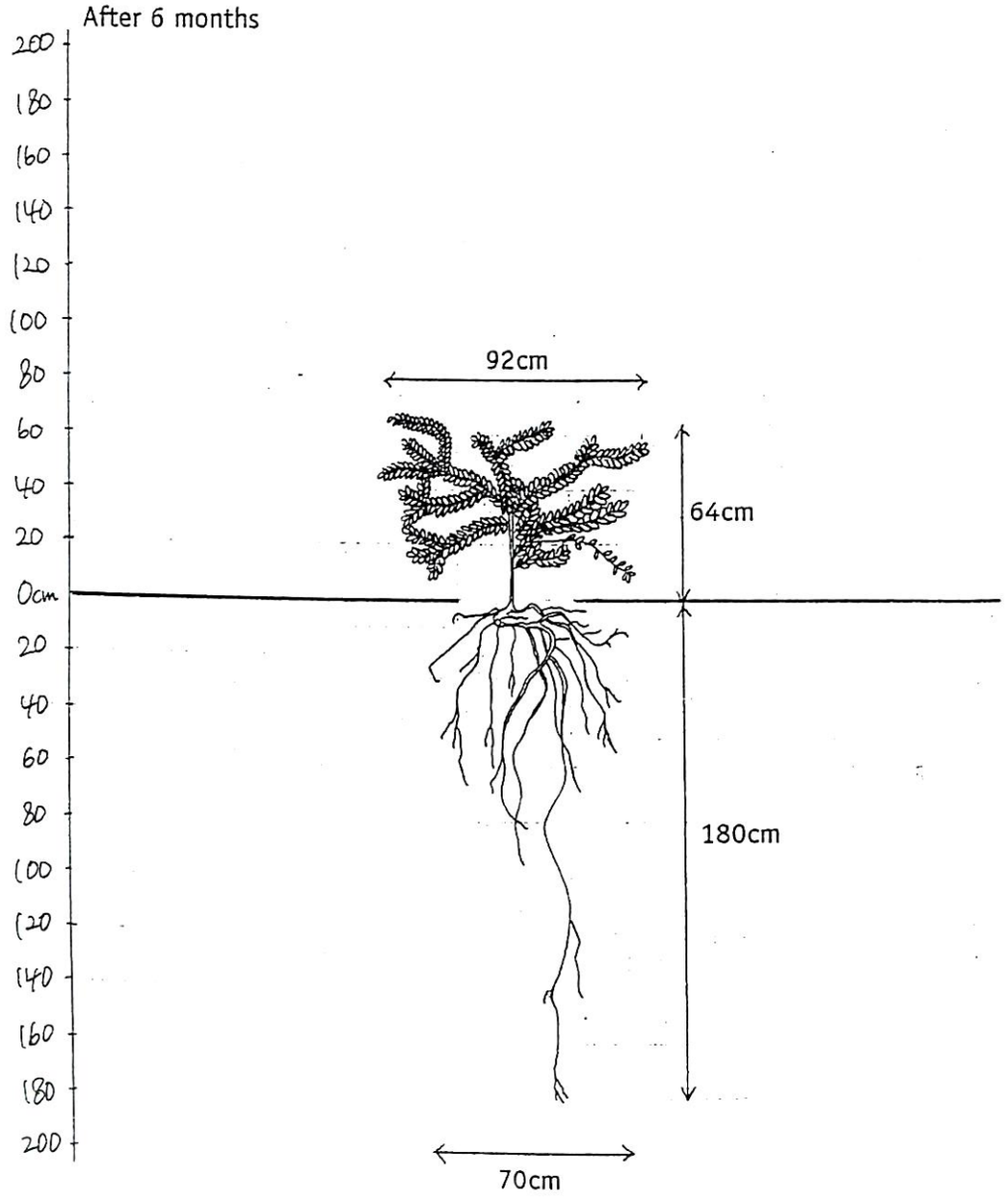


A-20) *Vitex doniana*

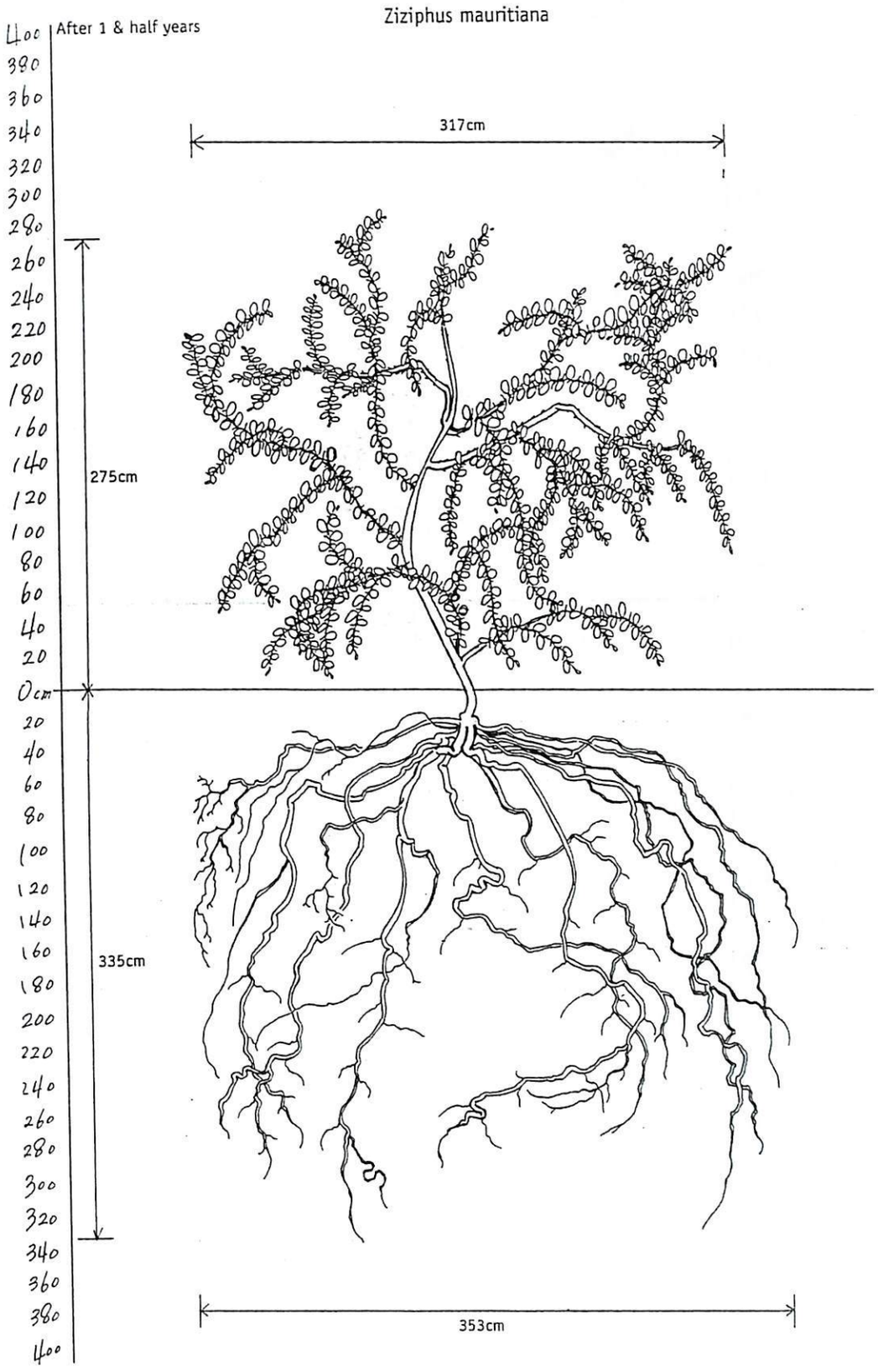


A-21) *Ziziphus mauritiana*

Ziziphus mauritiana

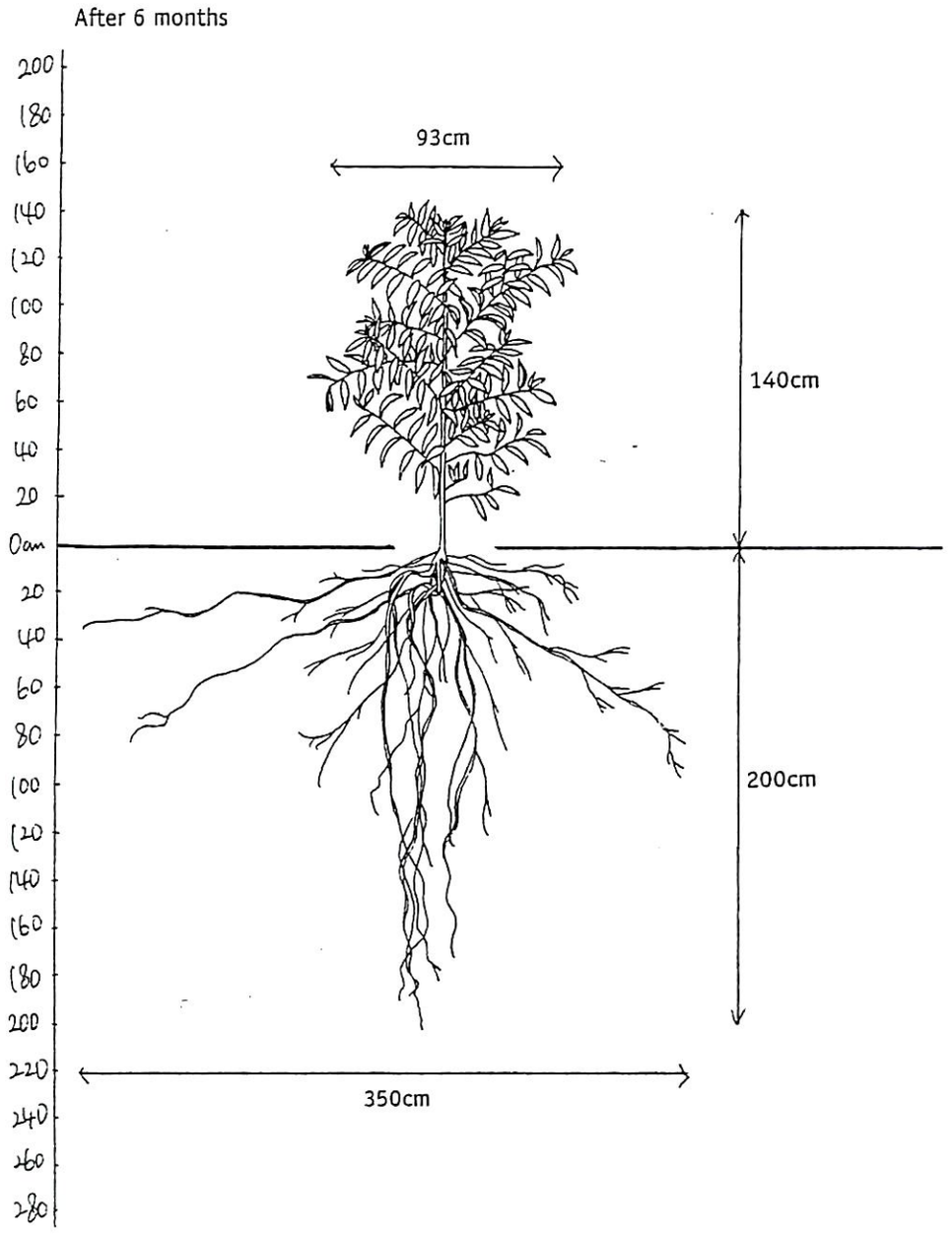


A-21) *Ziziphus mauritiana*

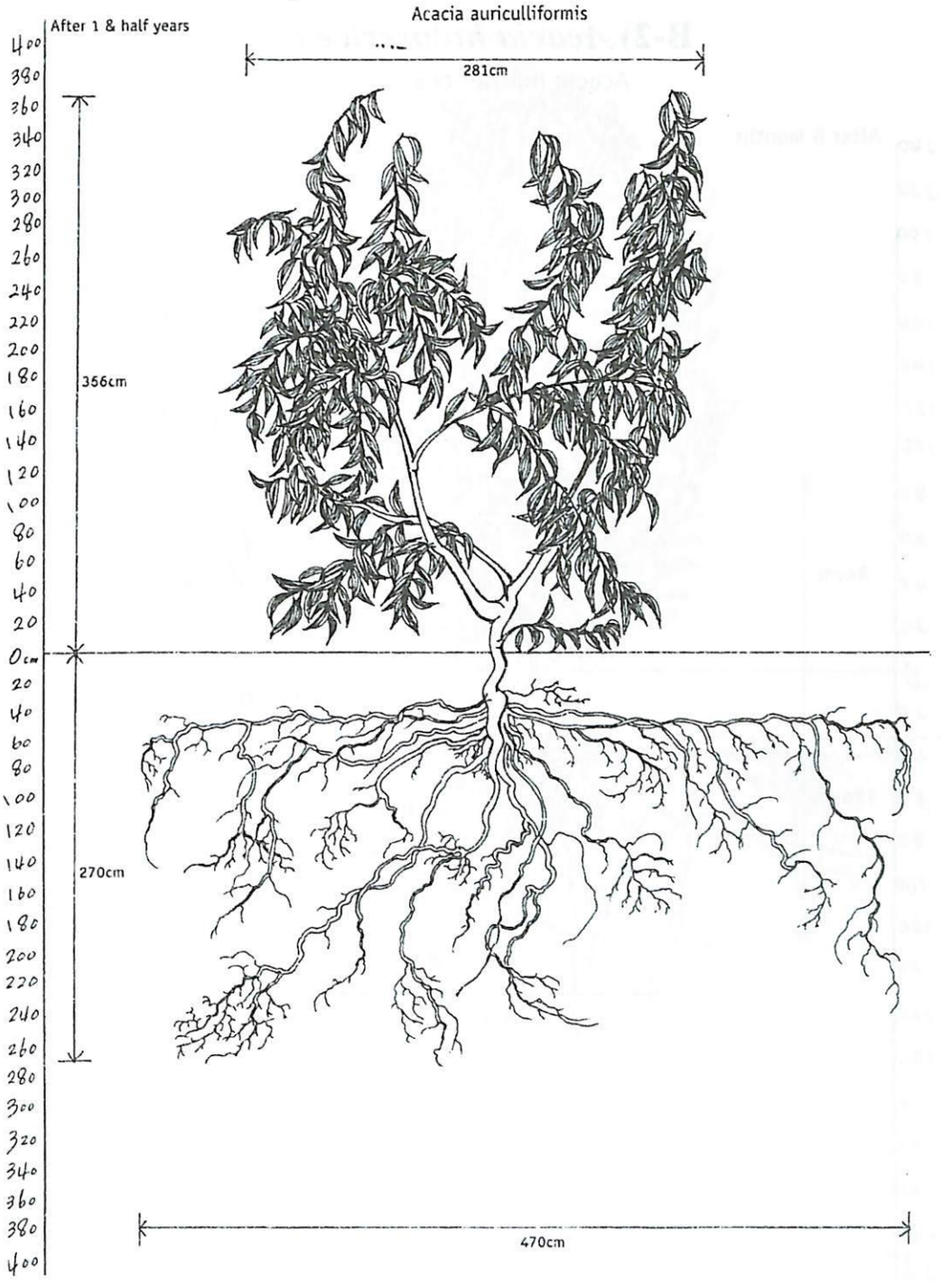


B-1) *Acacia auriculliformis*

Acacia auriculliformis

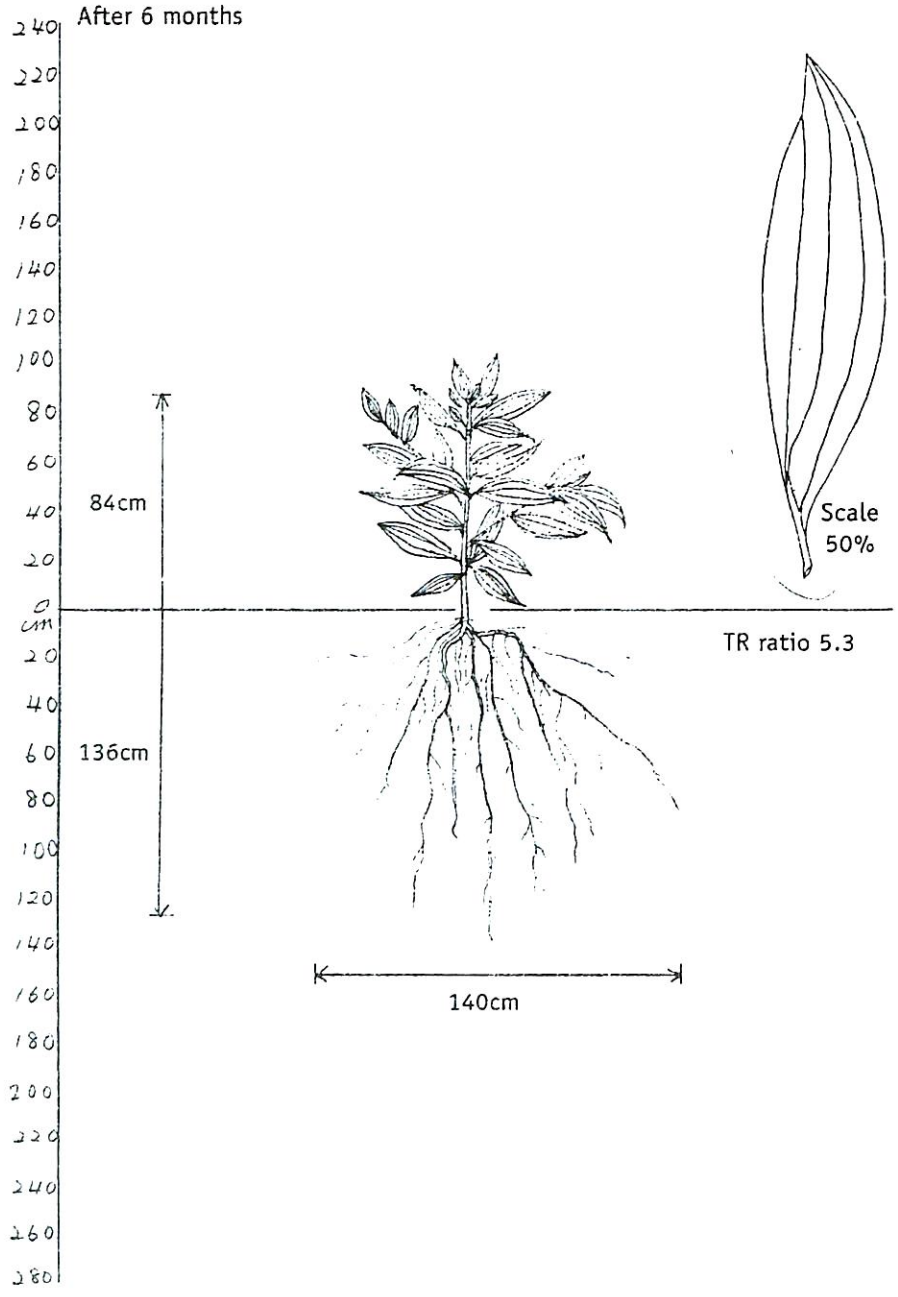


B-1) *Acacia auriculliformis*

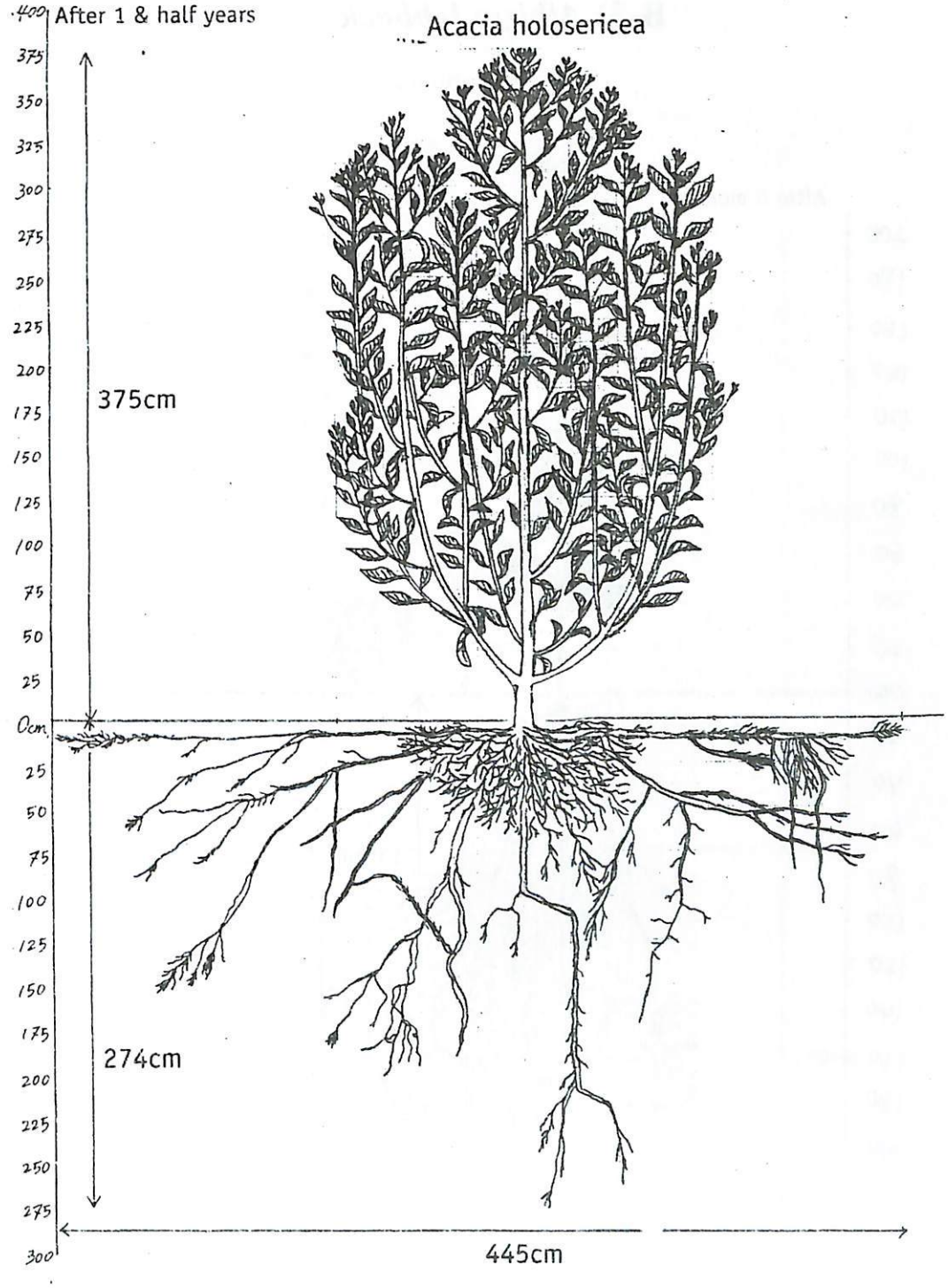


B-2) *Acacia holosericea*

Acacia holosericea

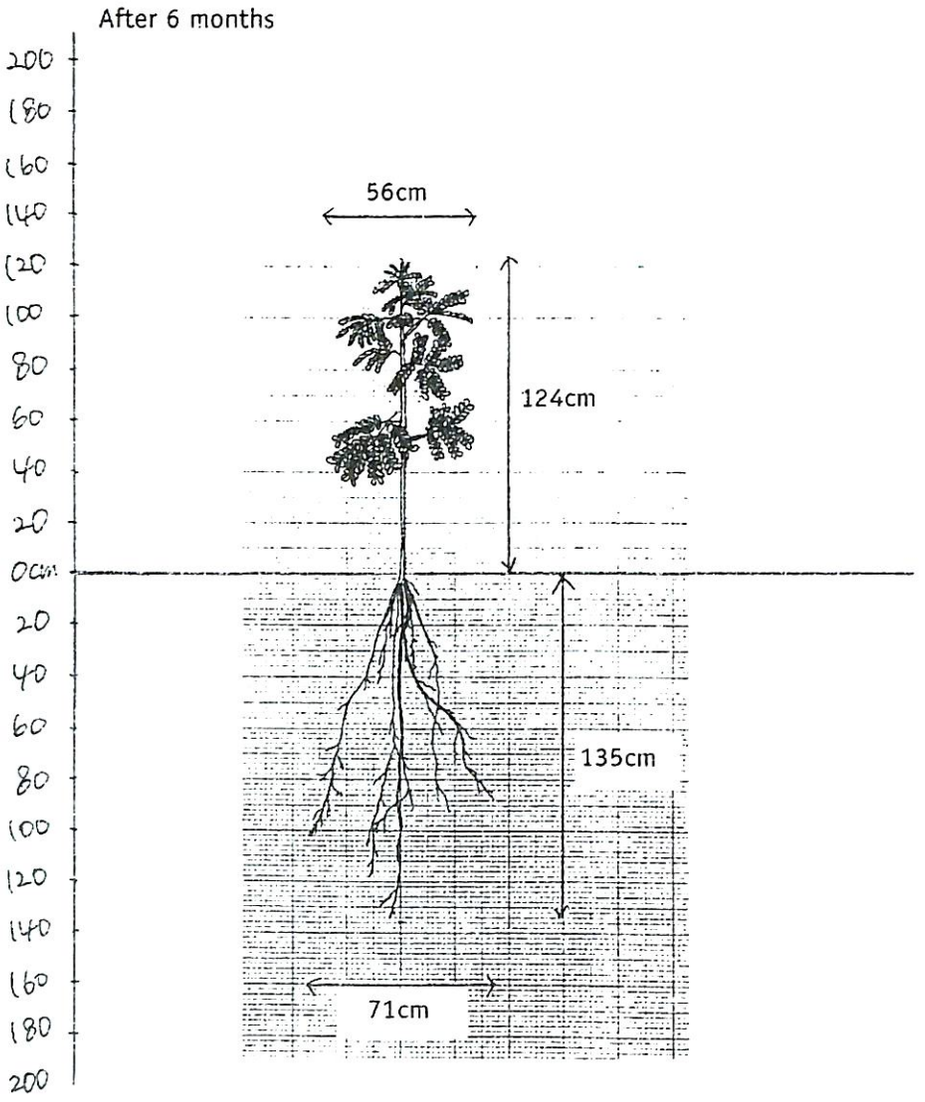


B-2) *Acacia holosericea*

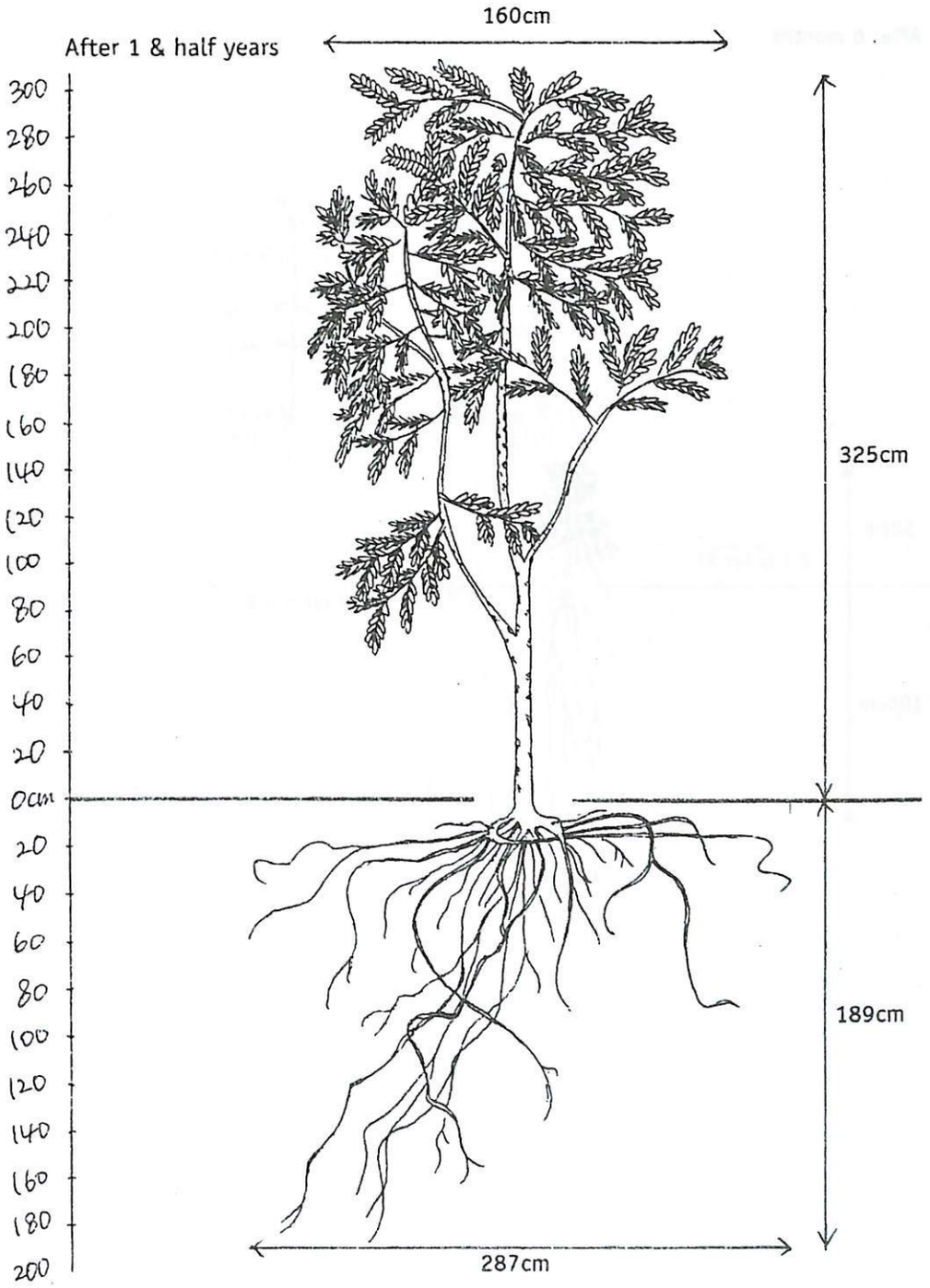


B-3) *Albizia lebbeck*

Albizia lebbeck

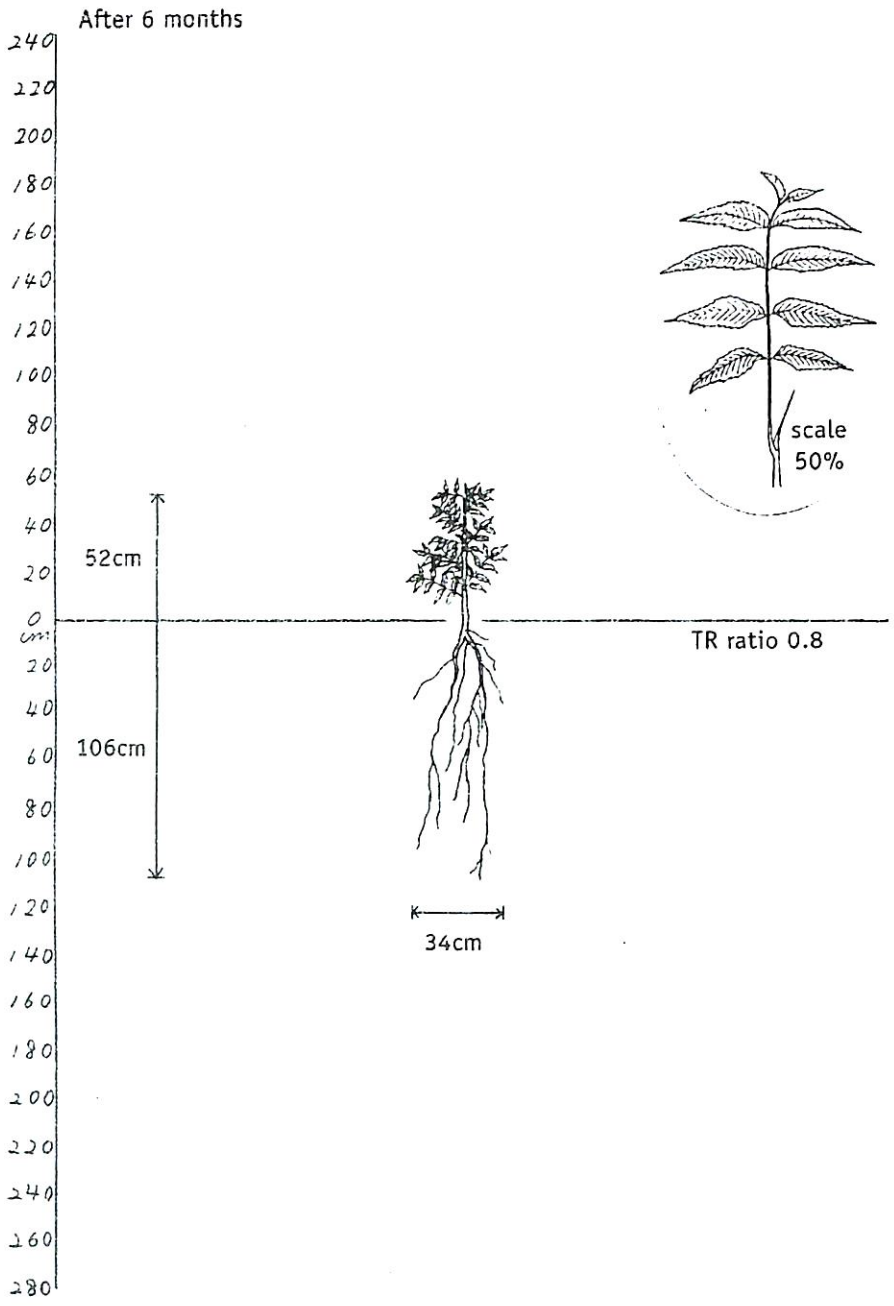


B-3) *Albizia lebbeck*



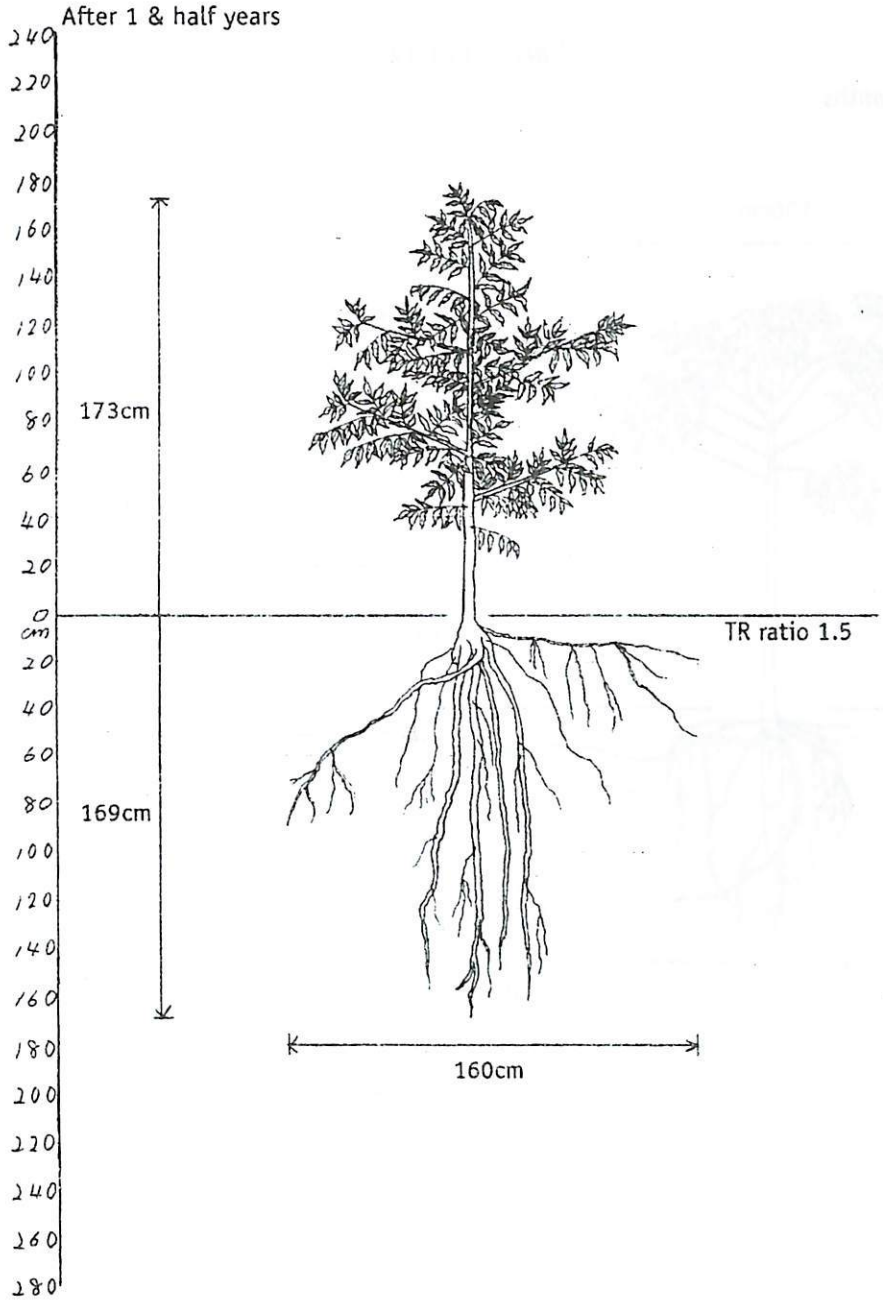
B-4) *Azadirachta indica*

Azadirachta indica

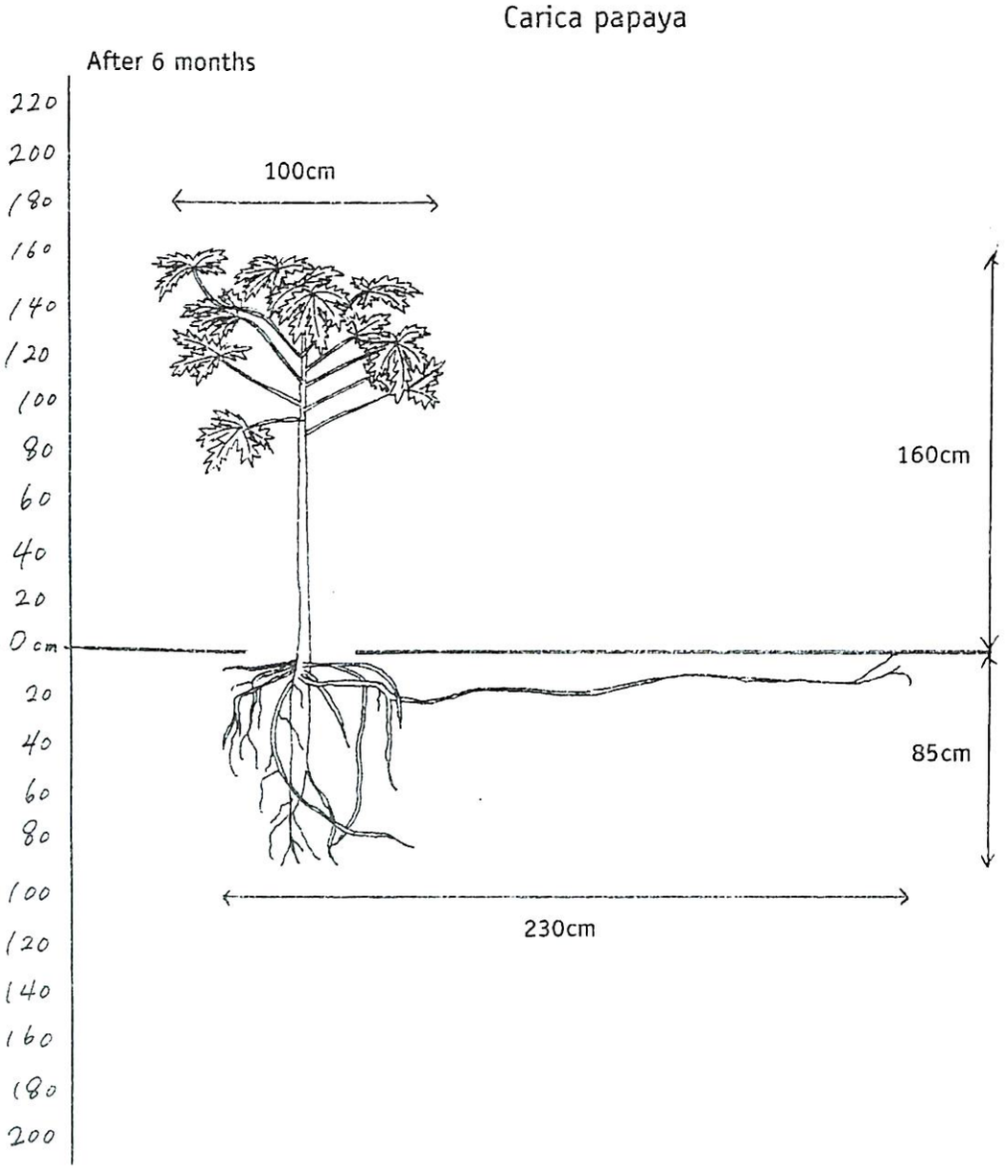


B-4) *Azadirachta indica*

Azadirachta indica

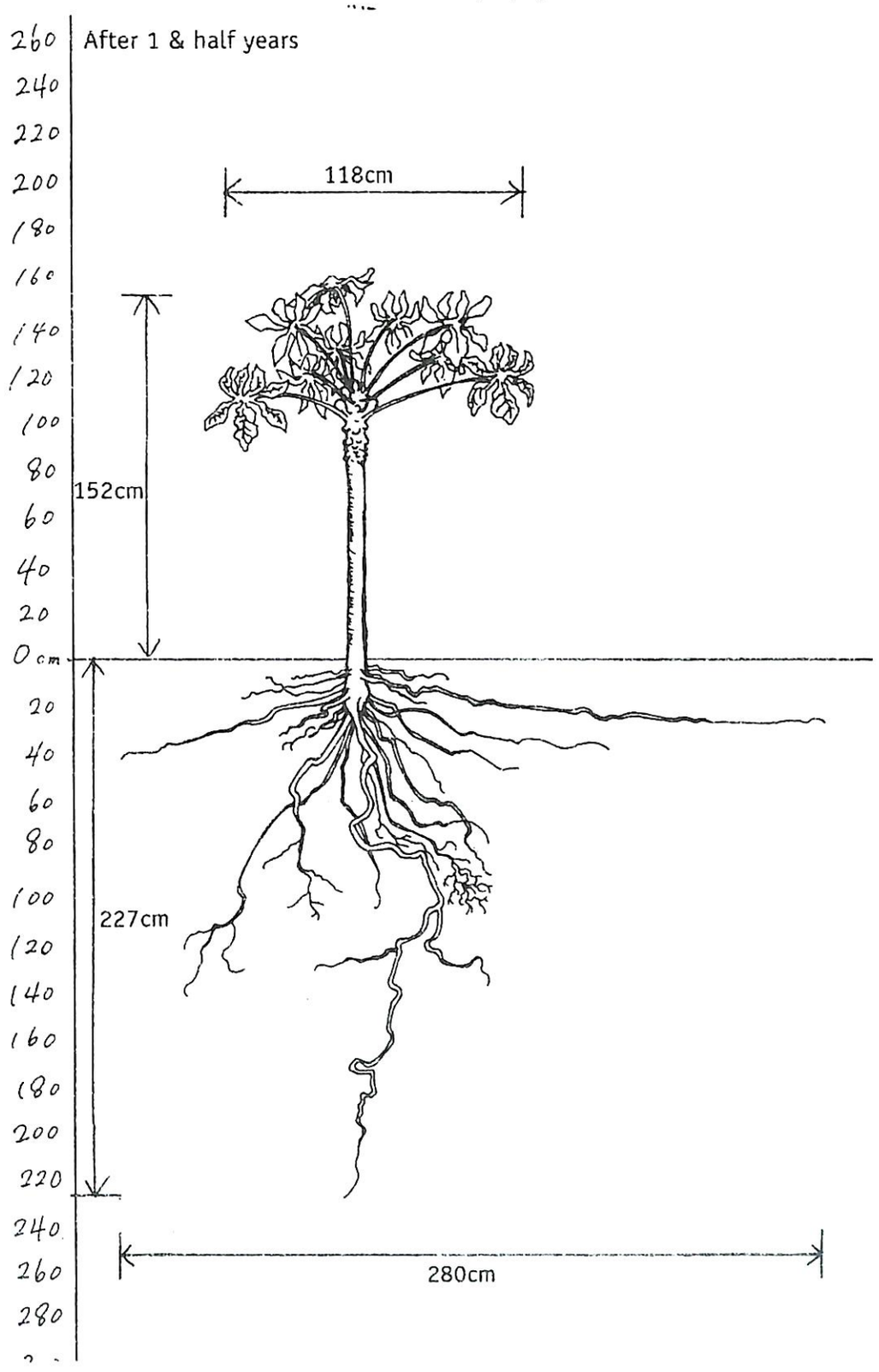


B-5) *Carica papaya*



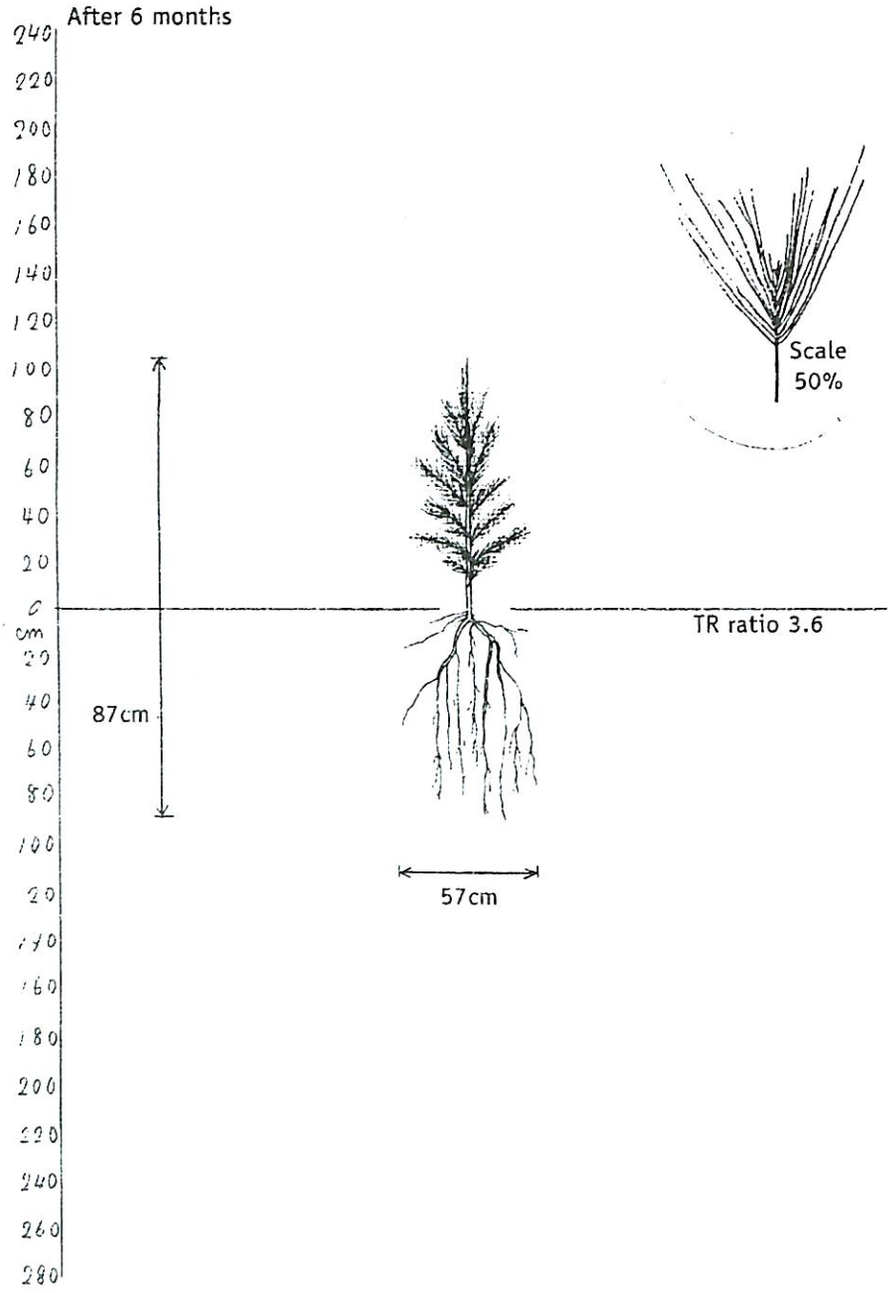
B-5) *Carica papaya*

Carica papaya



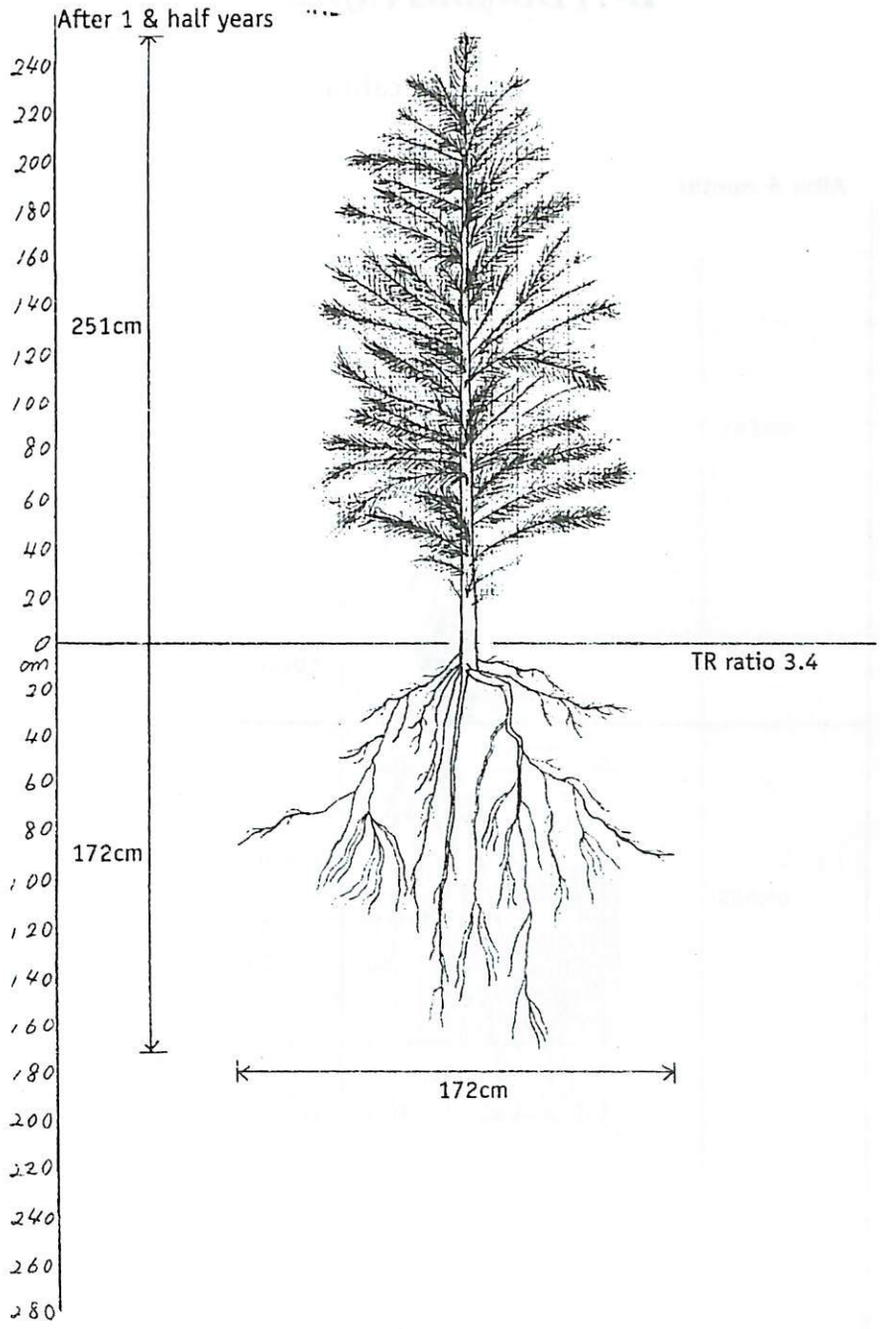
B-6) *Casuarina equisetifolia*

Casuarina equisetifolia



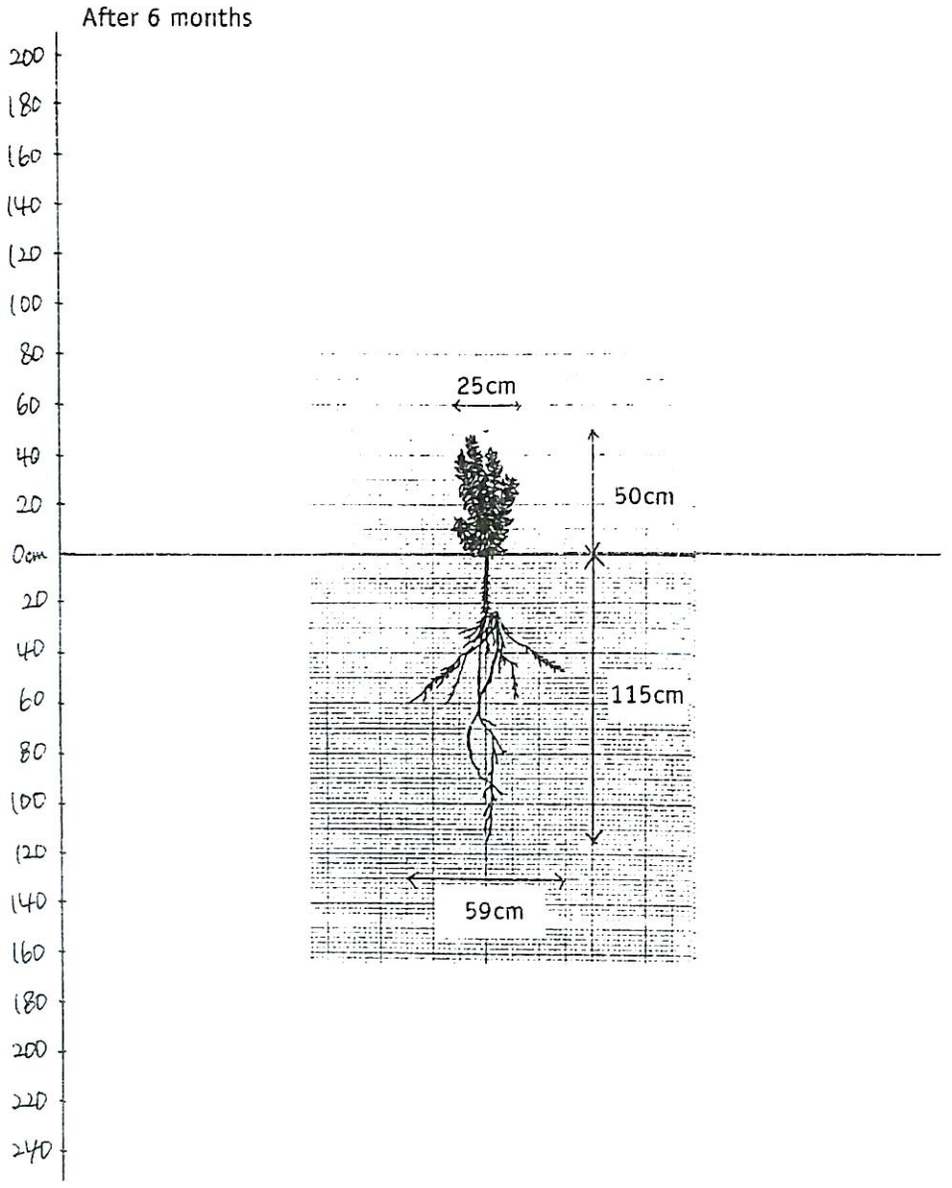
B-6) *Casuarina equisetifolia*

Casuarina equisetifolia



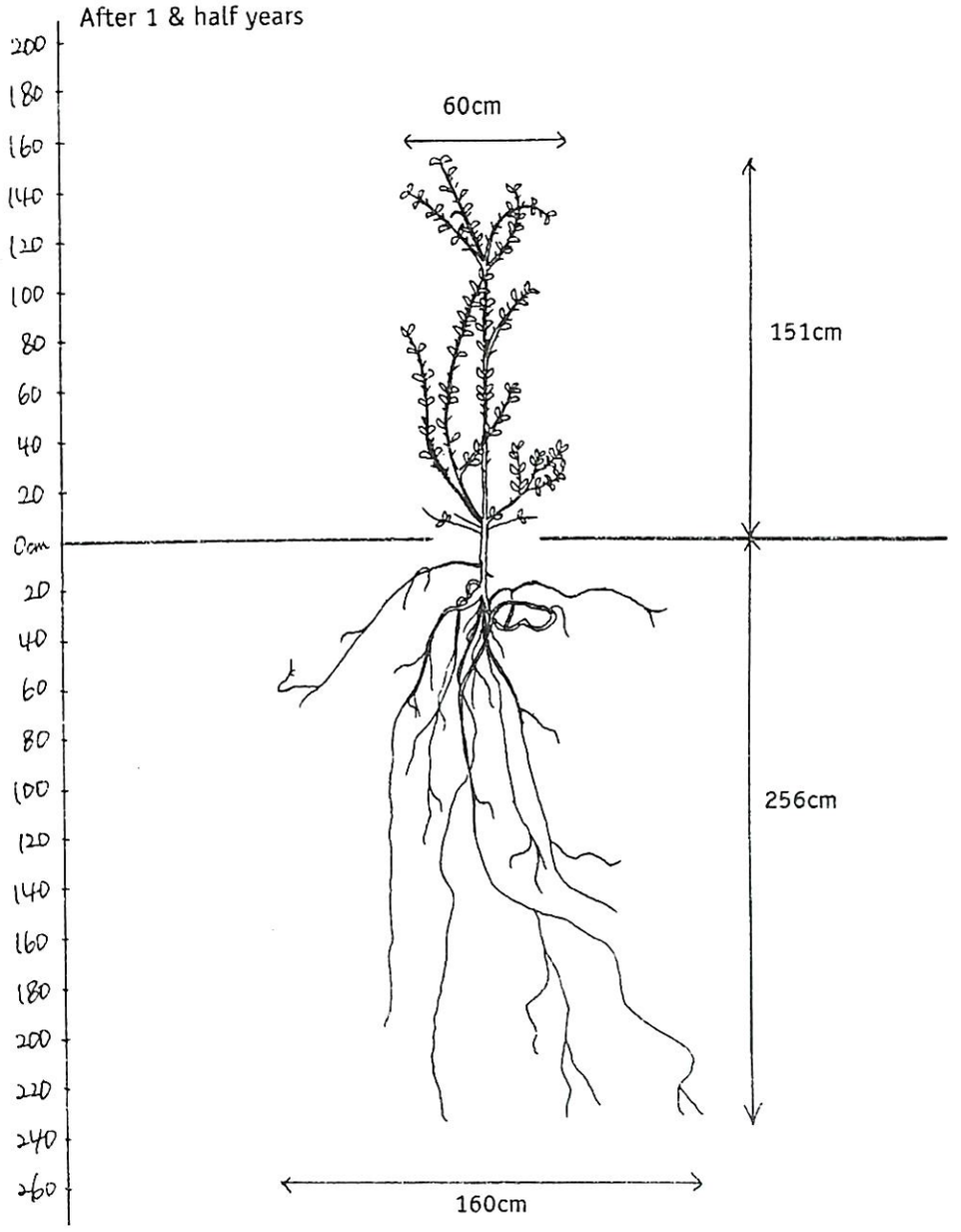
B-7) *Dovyalis caffra*

Dovyalis caffra



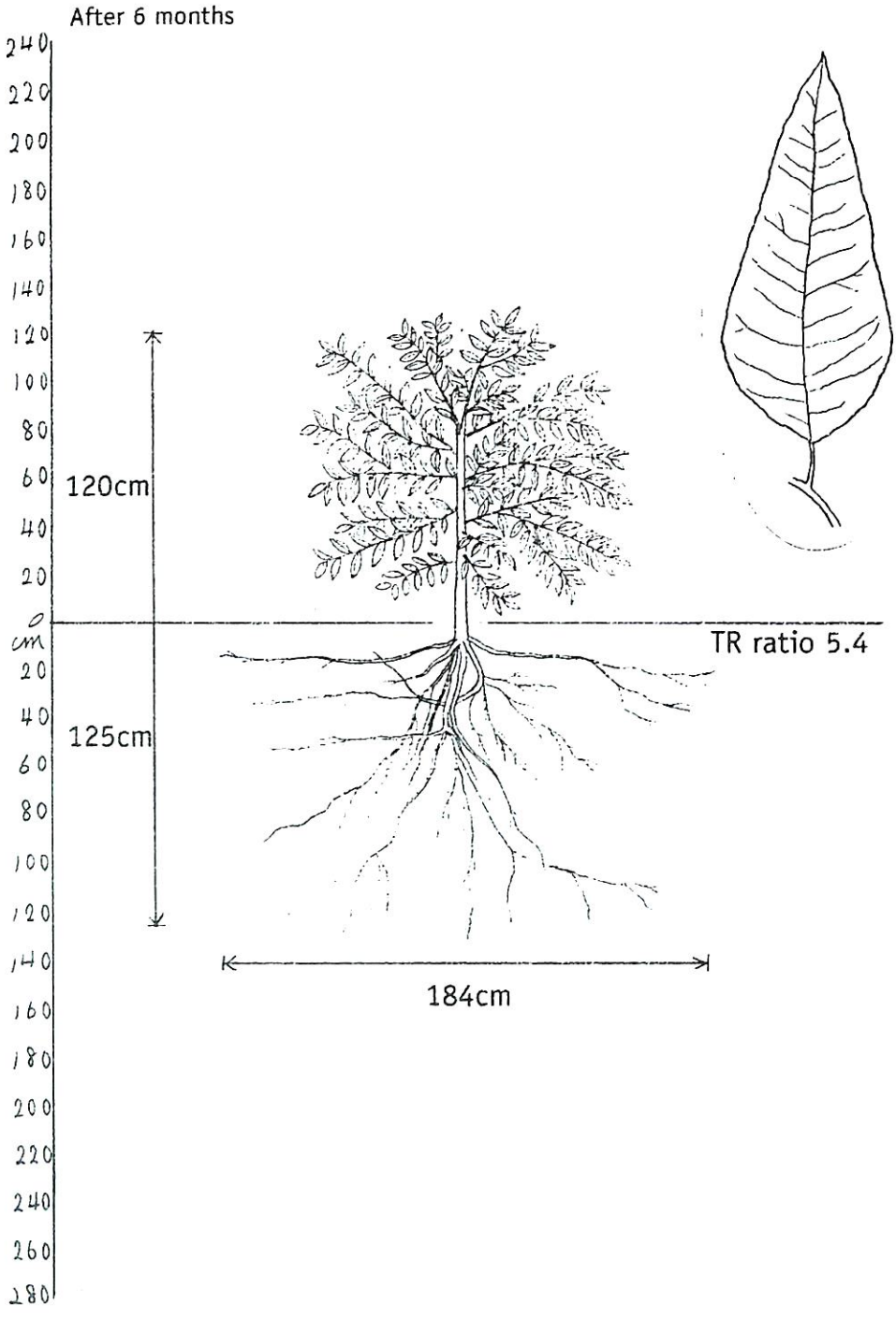
B-7) *Dovyalis caffra*

Dovyalis caffra

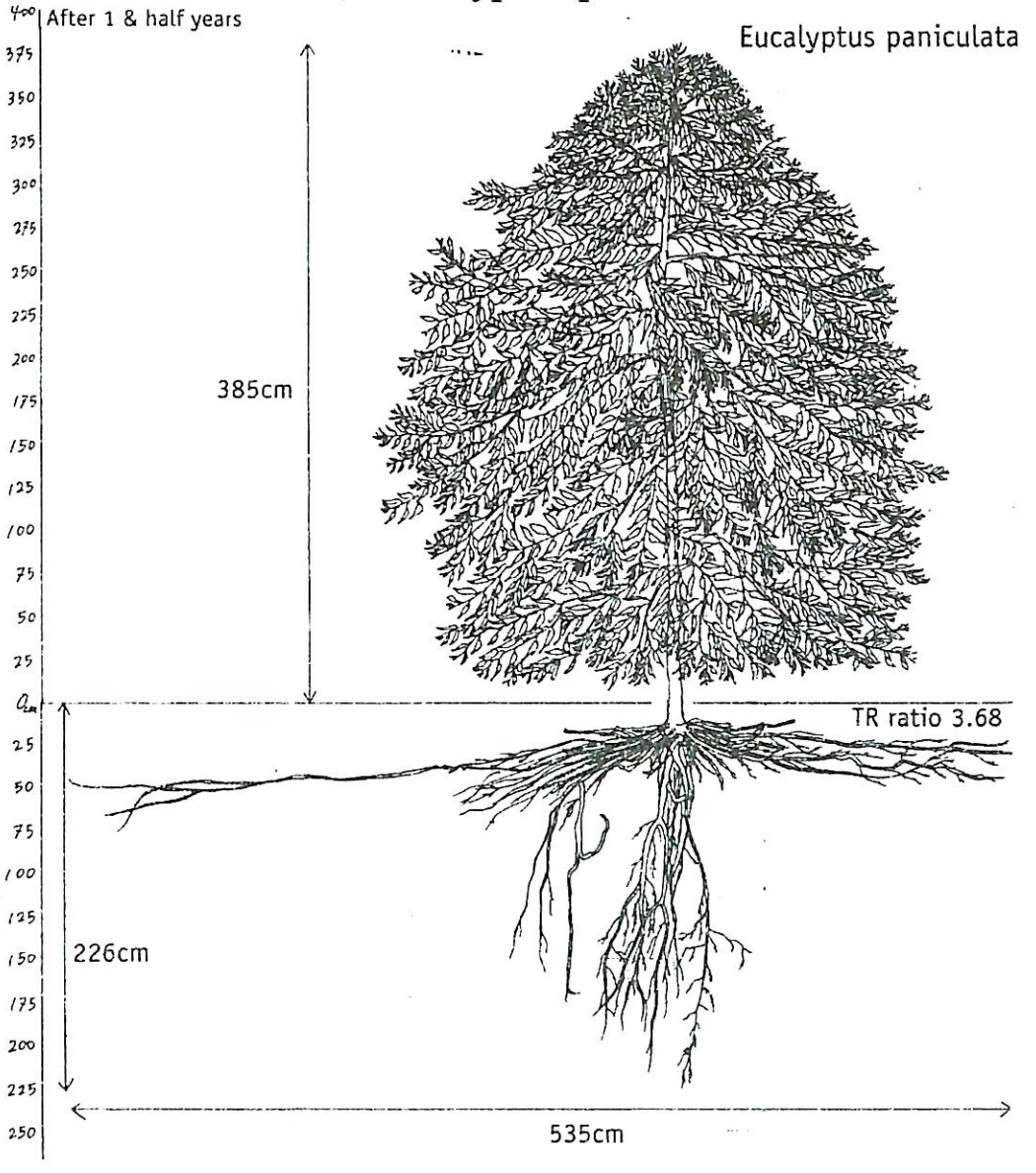


B-8) *Eucalyptus paniculata*

Eucalyptus paniculata

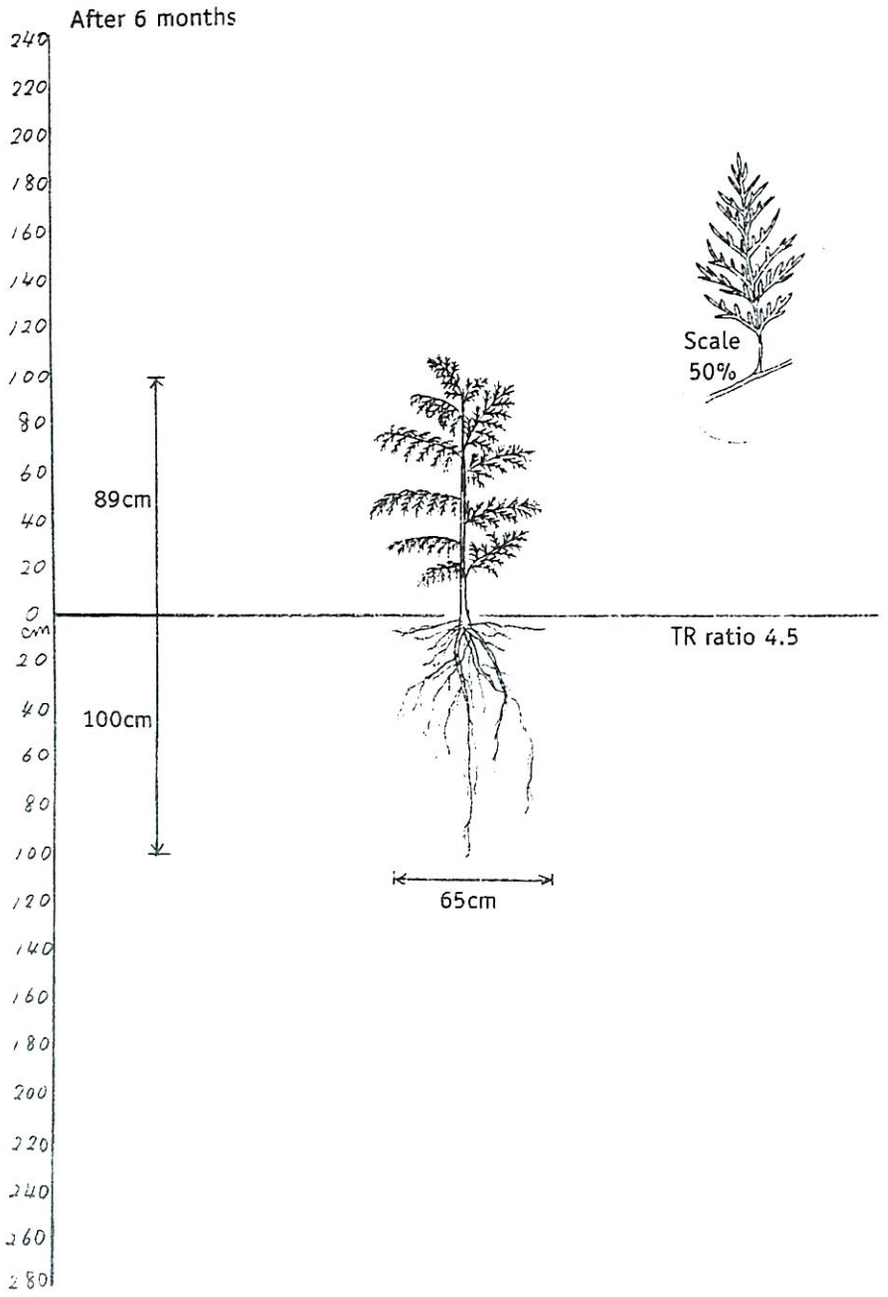


B-8) *Eucalyptus paniculata*



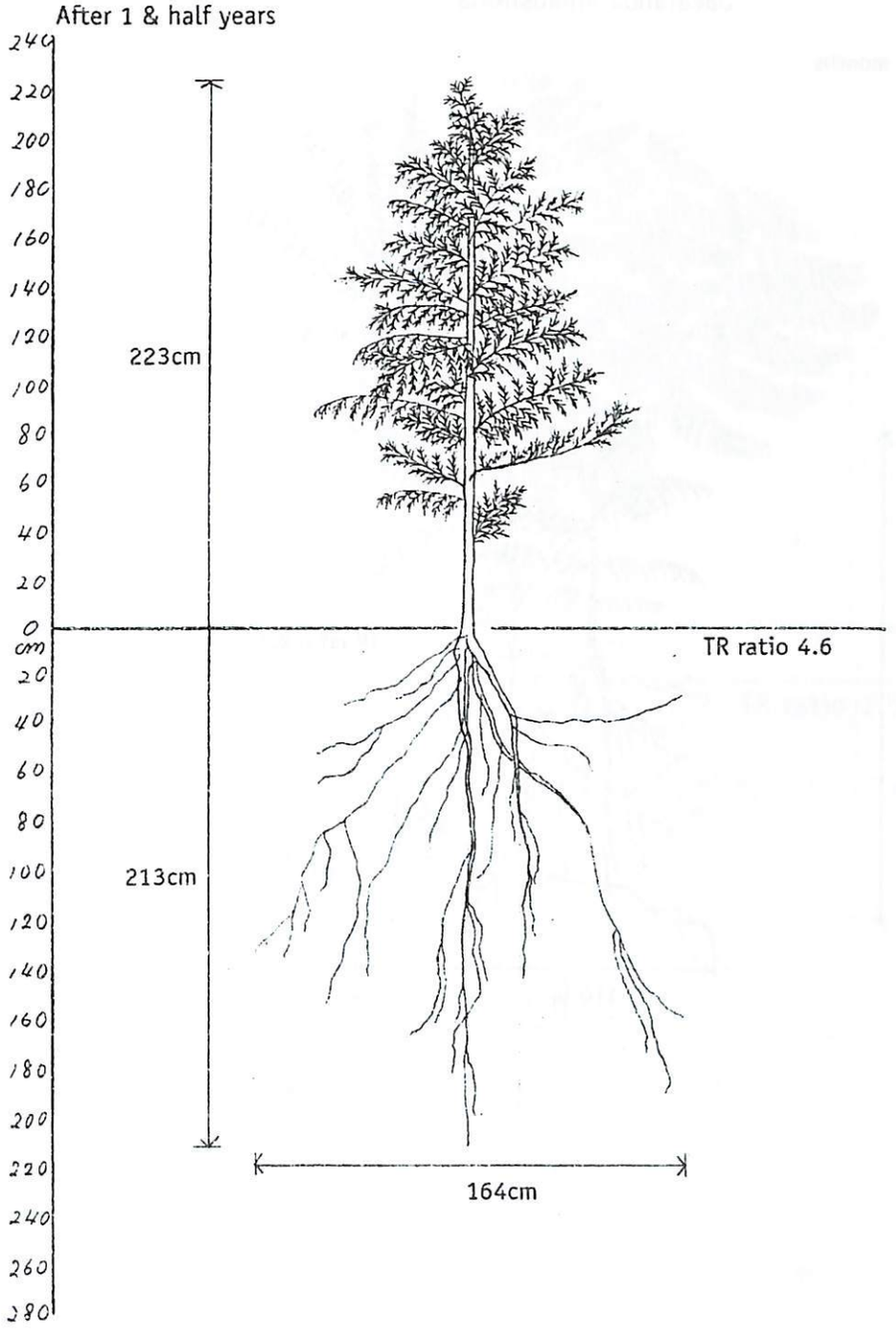
B-9) *Grevillea robusta*

Grevillea robusta



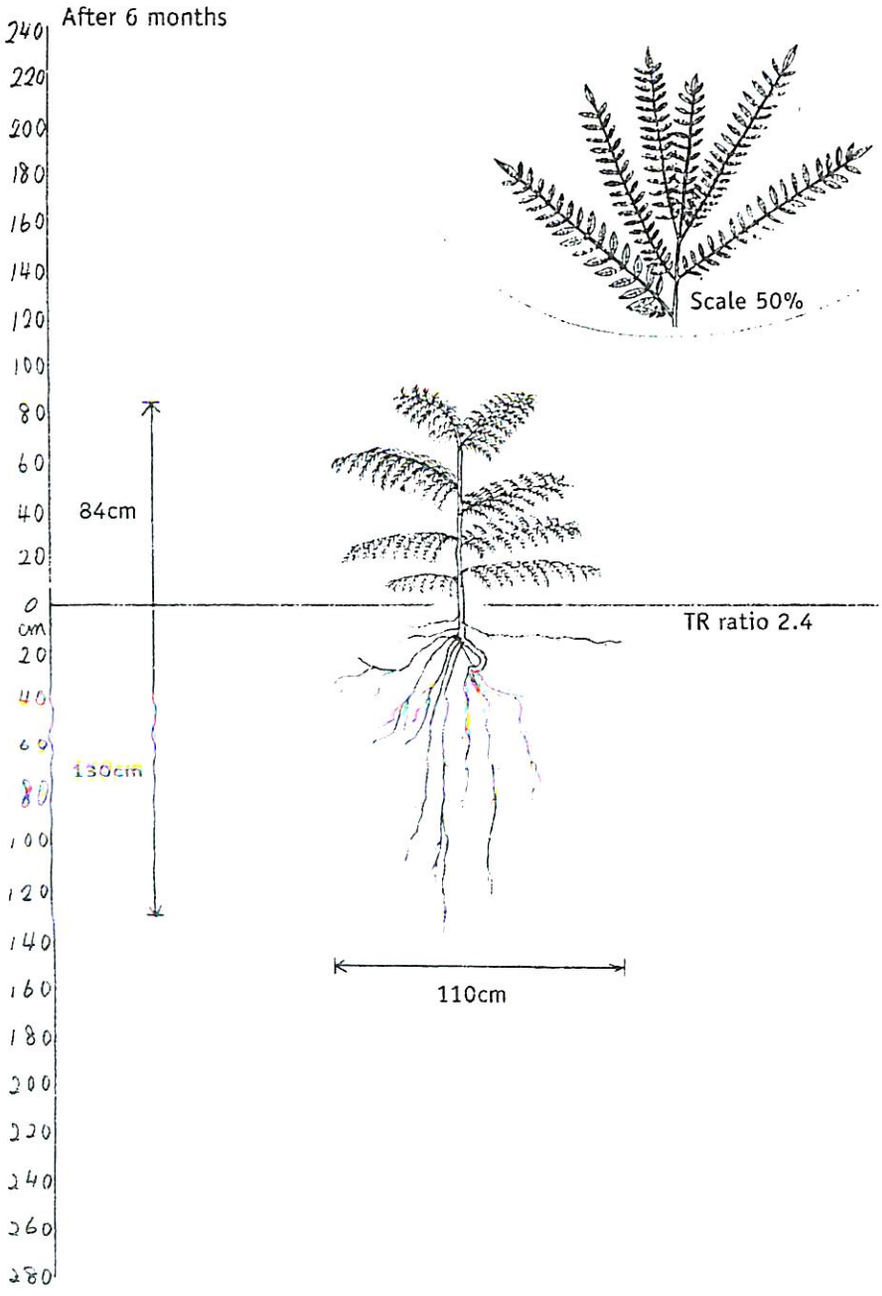
B-9) *Grevillea robusta*

Grevillea robusta

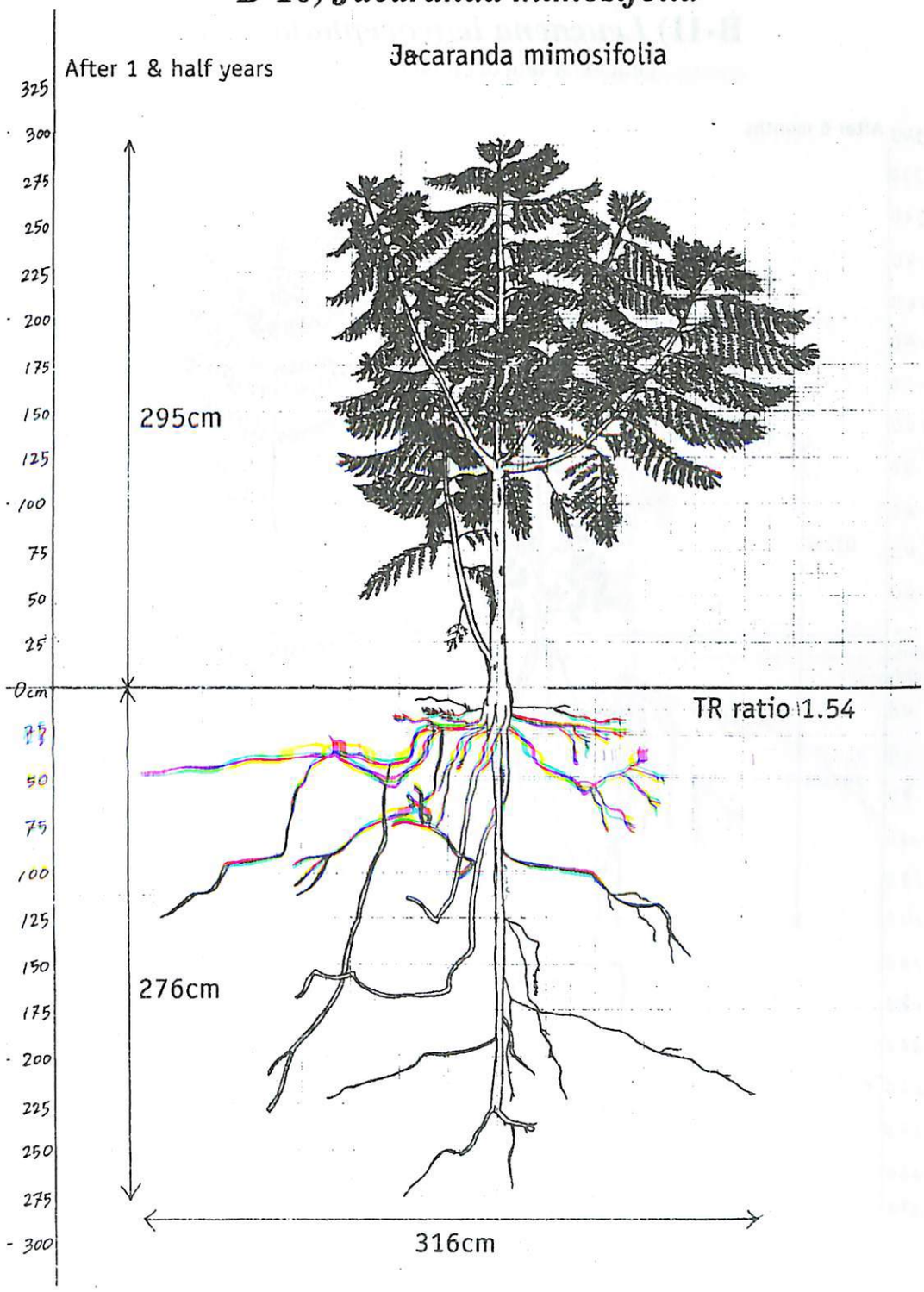


B-10) *Jacaranda mimosifolia*

Jacaranda mimosifolia

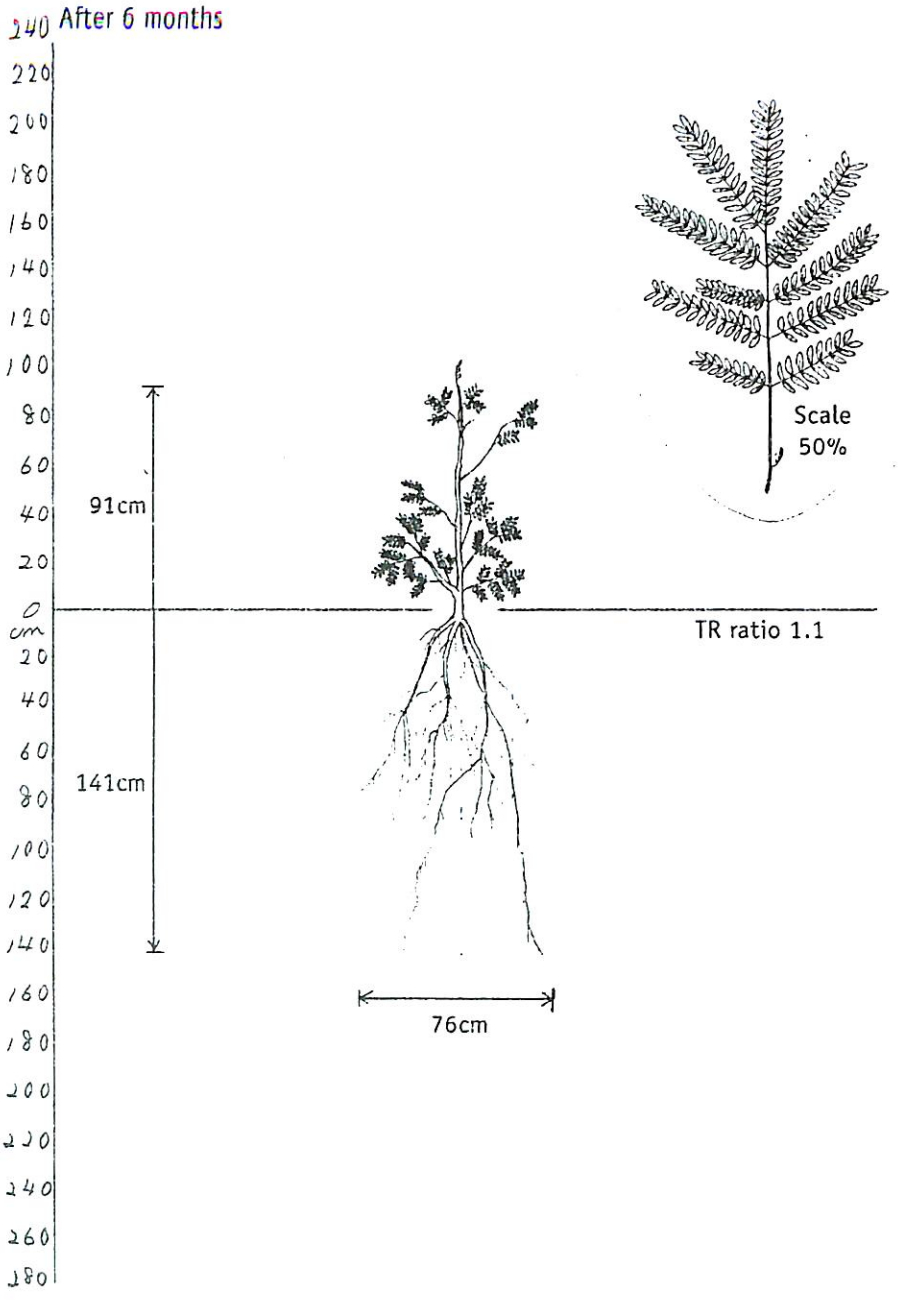


B-10) *Jacaranda mimosifolia*

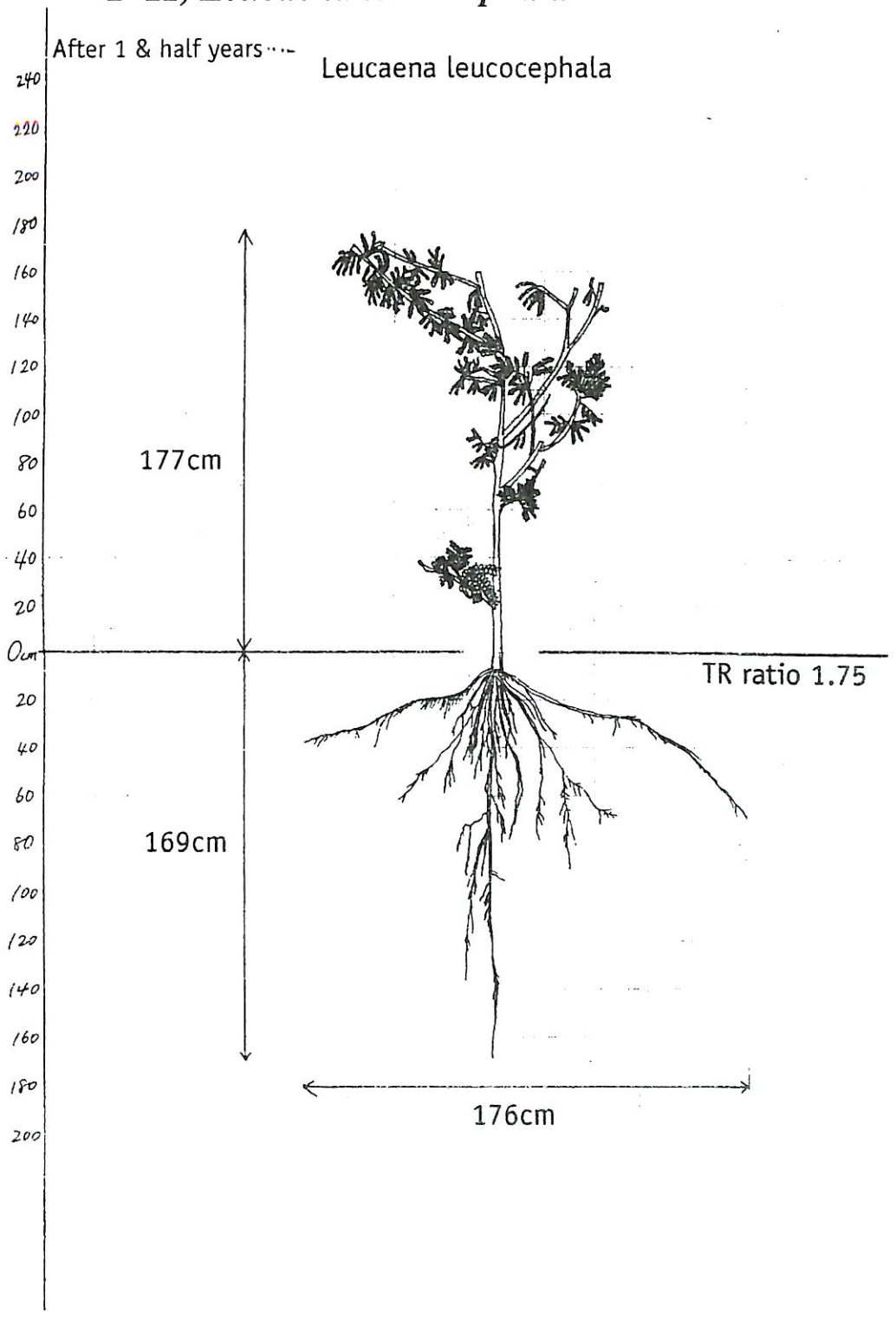


B-11) *Leucaena leucocephala*

Leucaena leucocephala

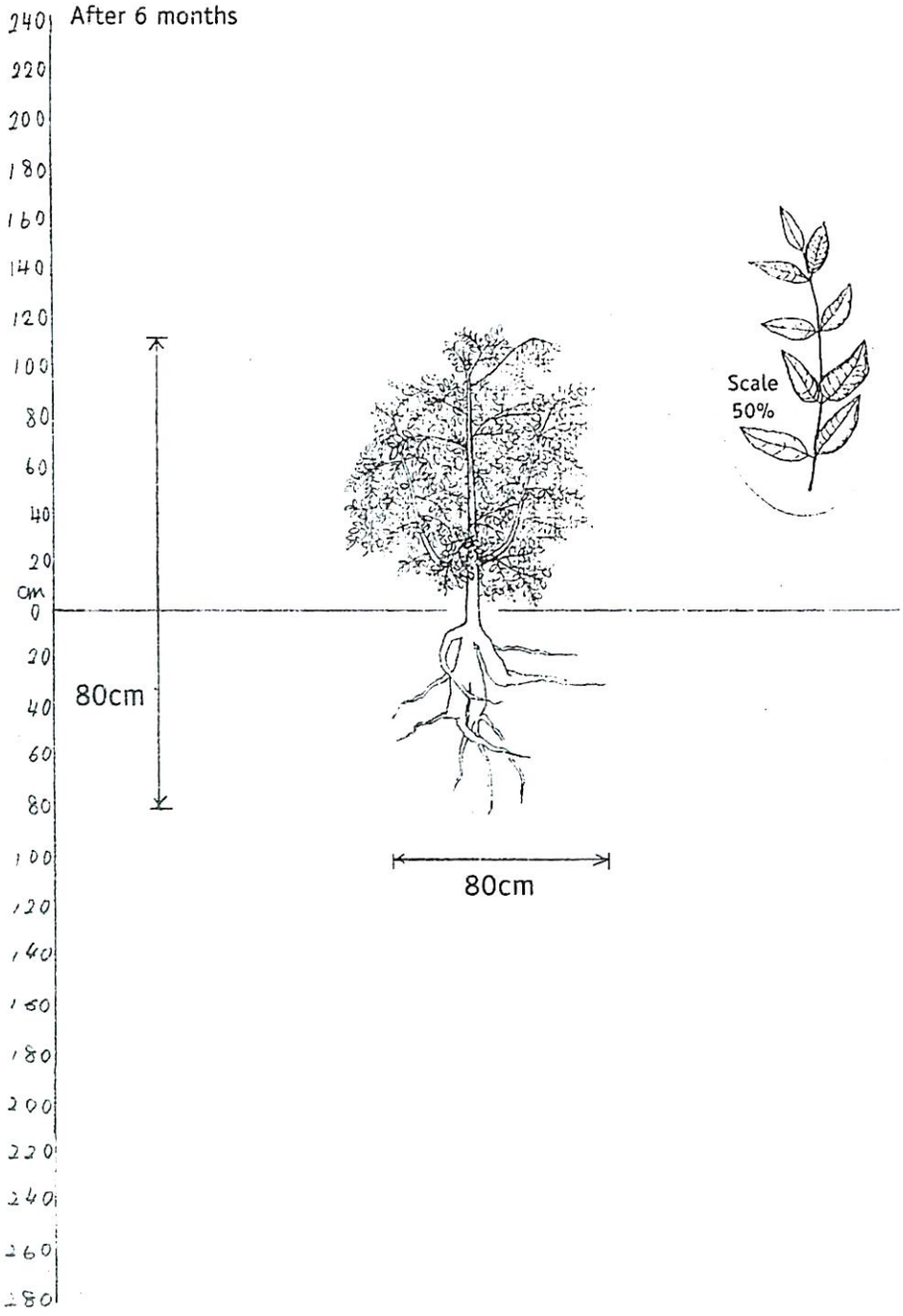


B-11) *Leucaena leucocephala*

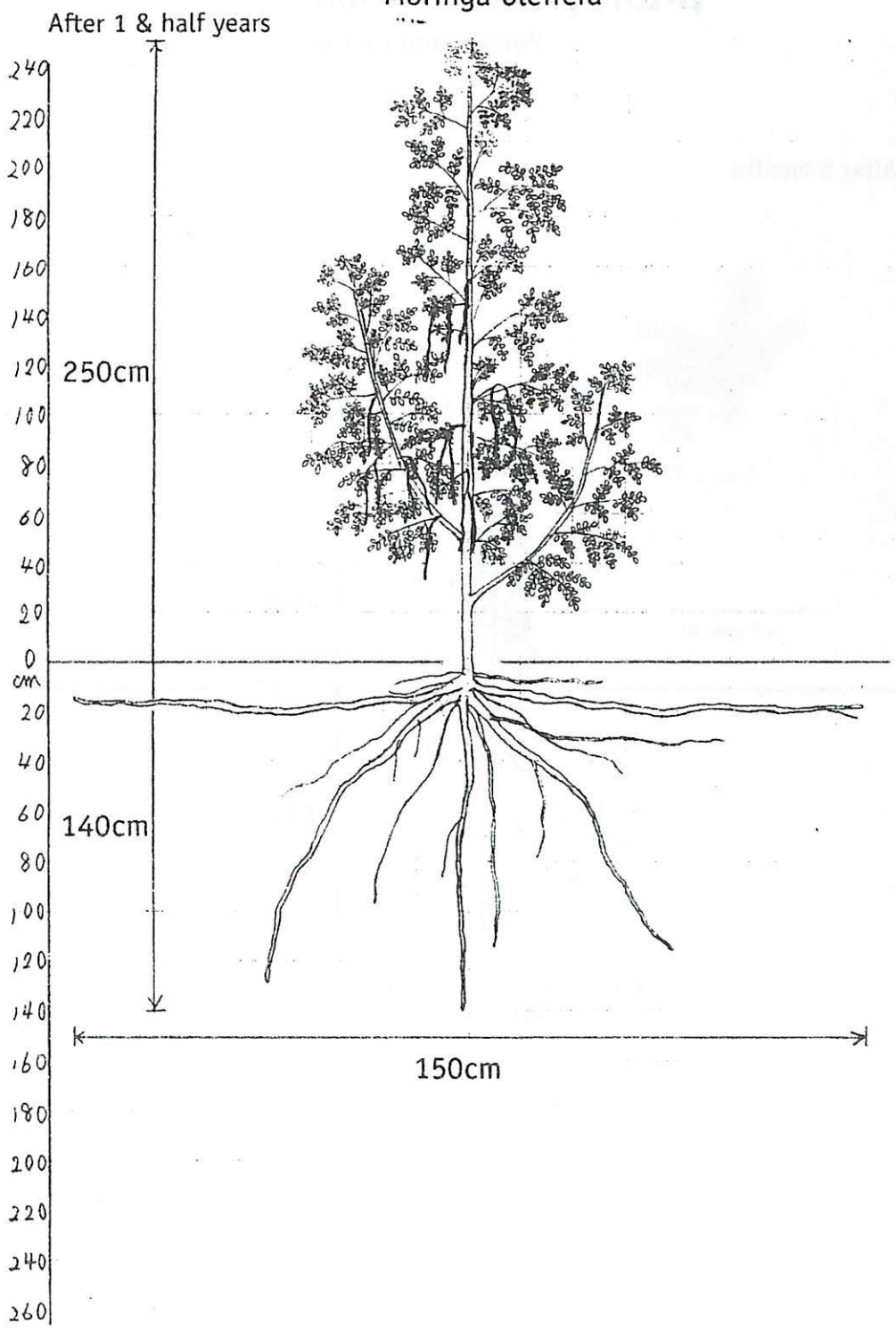


B-12) *Moringa oleifera*

Moringa oleifera

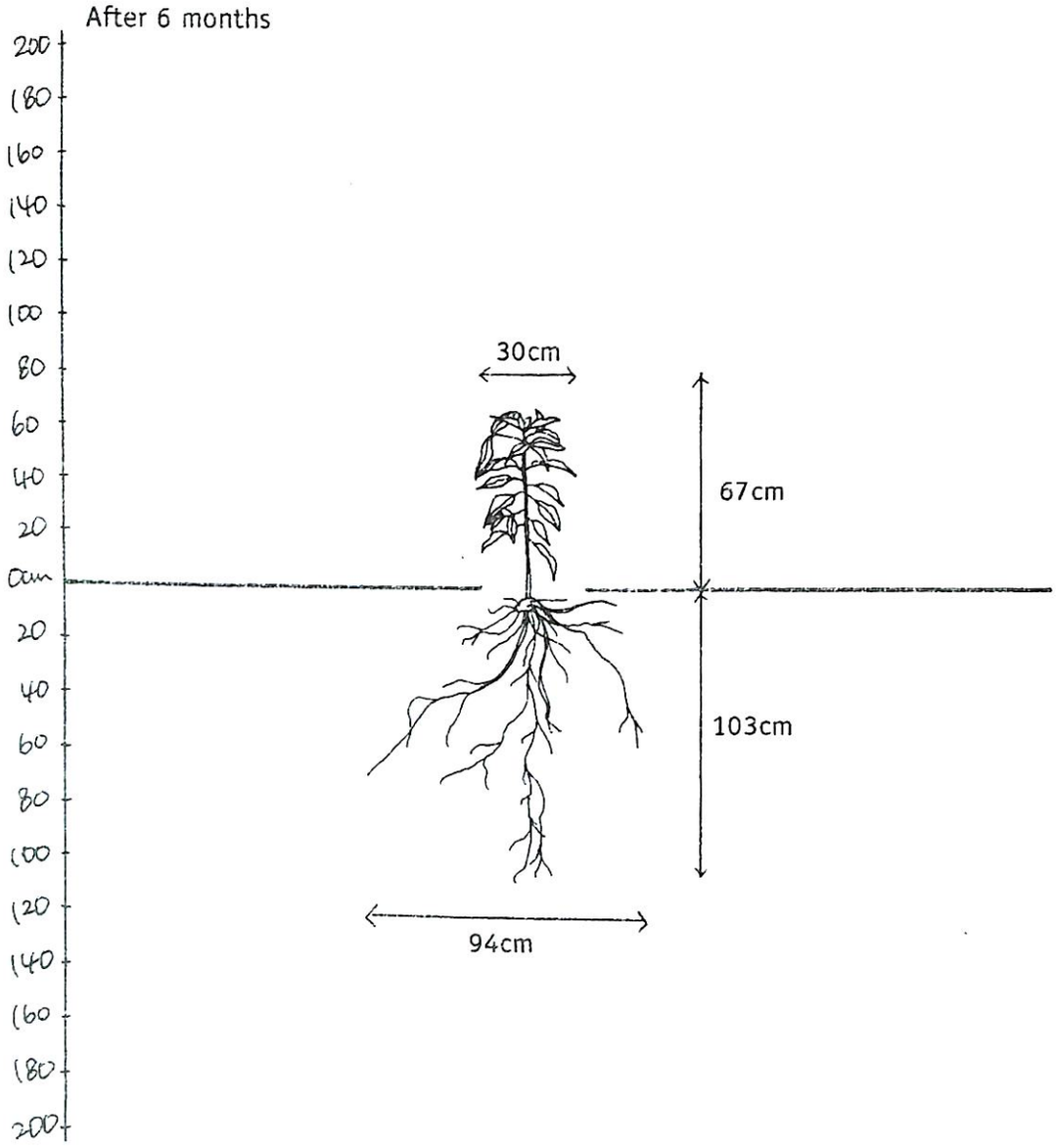


B-12) *Moringa oleifera*



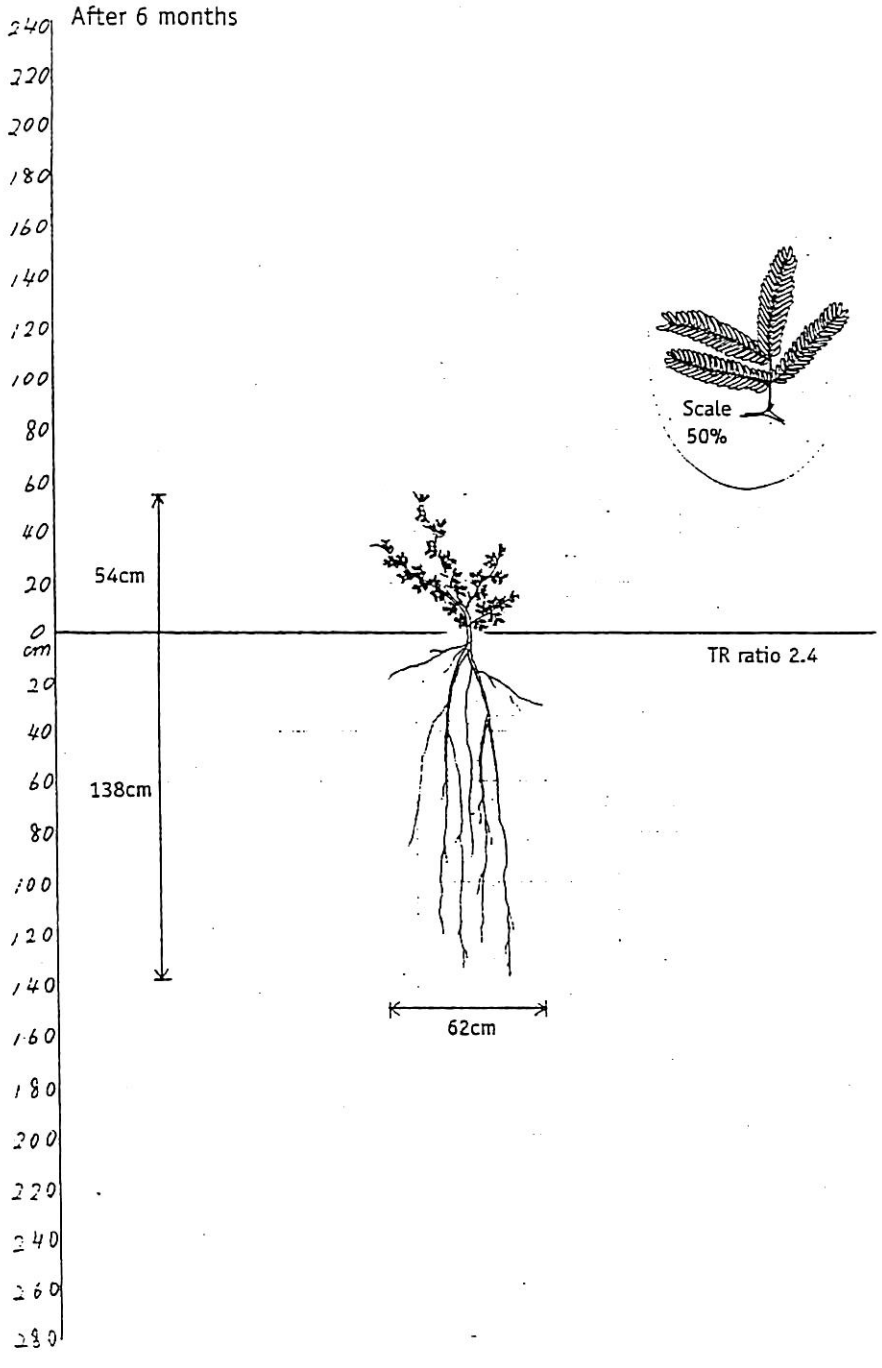
B-13) *Percea americana*

Percea americana



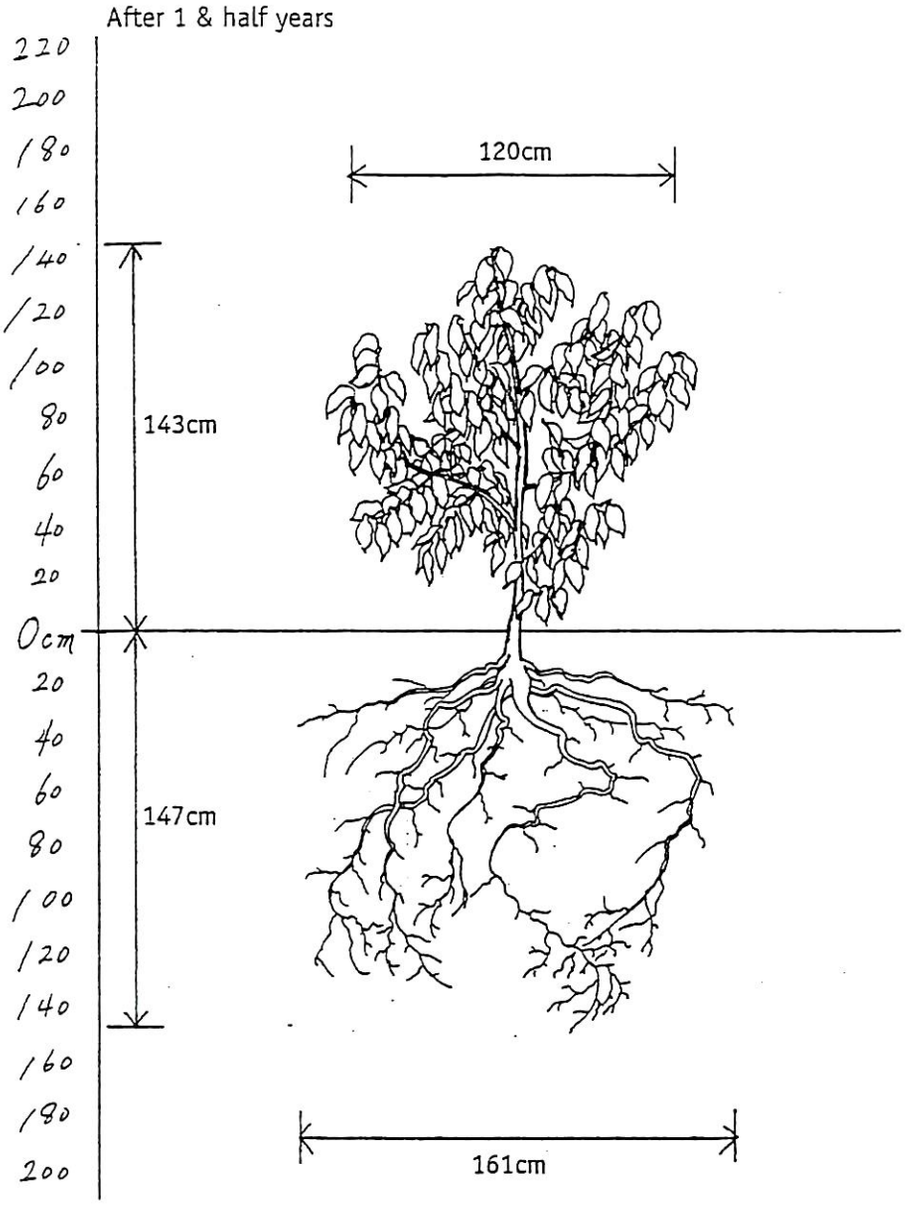
B-14) *Prosopis juliflora*

Prosopis juliflora



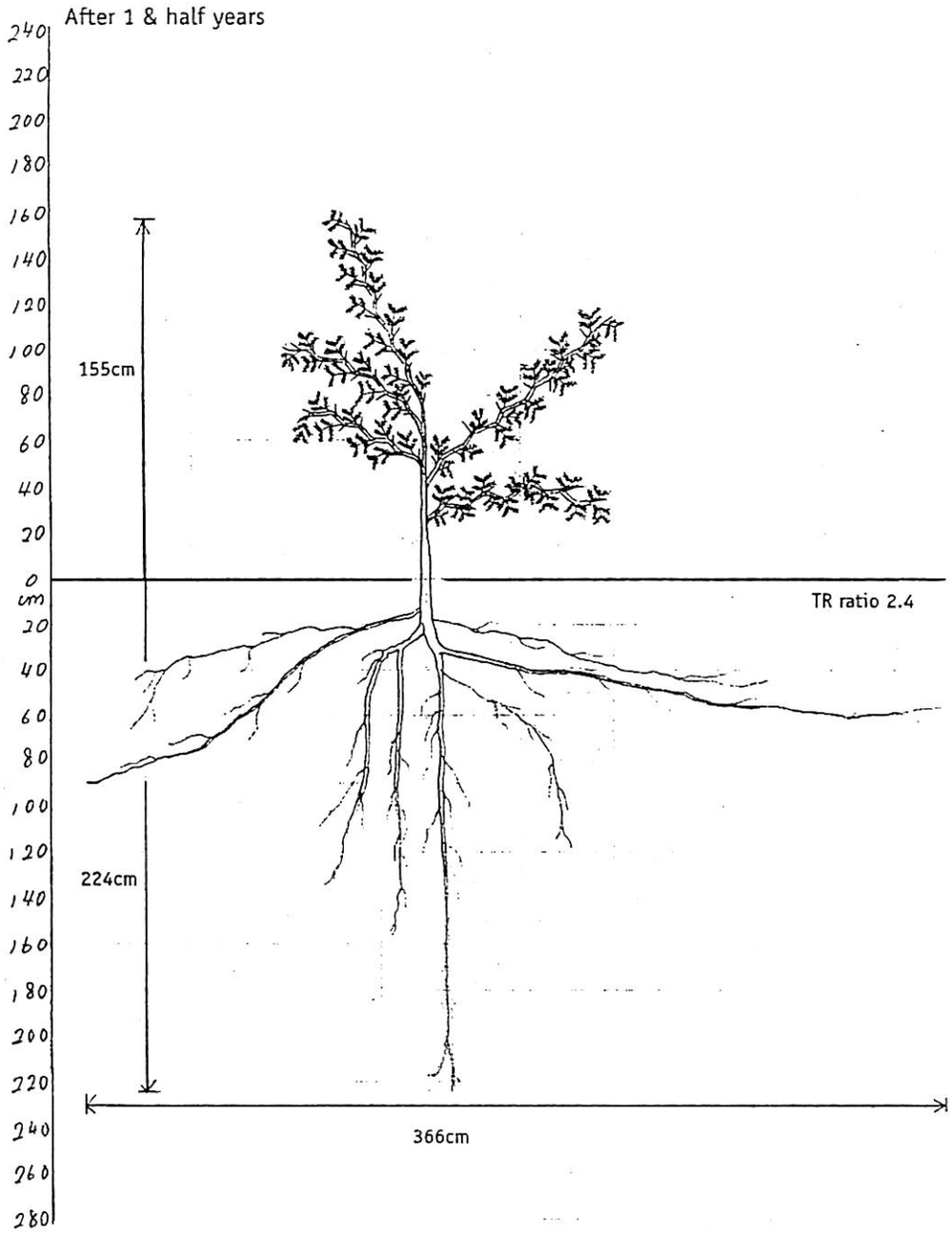
B-13) *Percea americana*

Percea americana



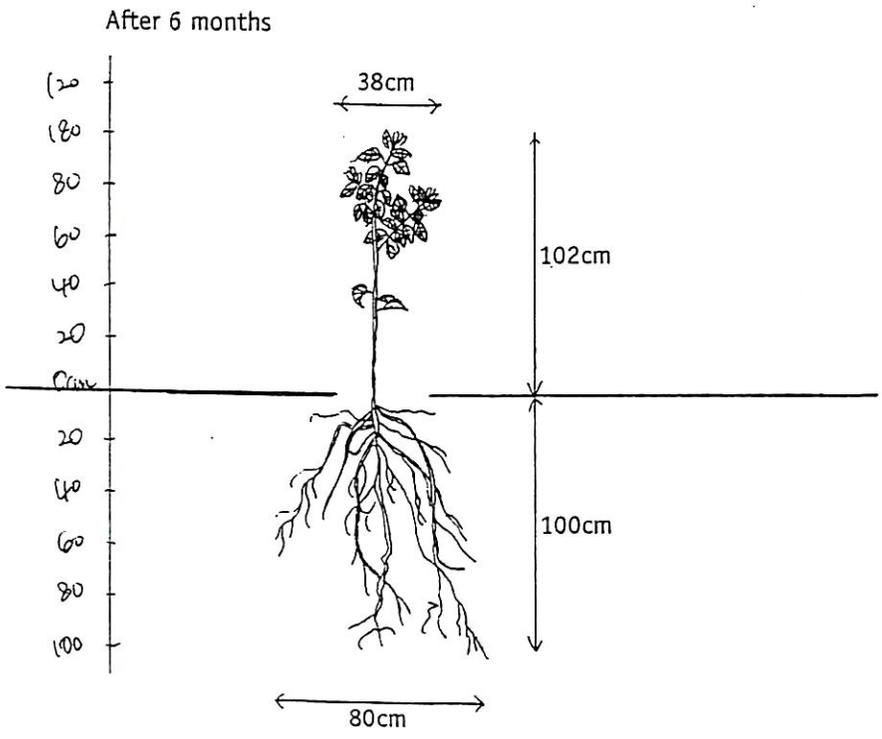
B-14) *Prosopis juliflora*

Prosopis juliflora

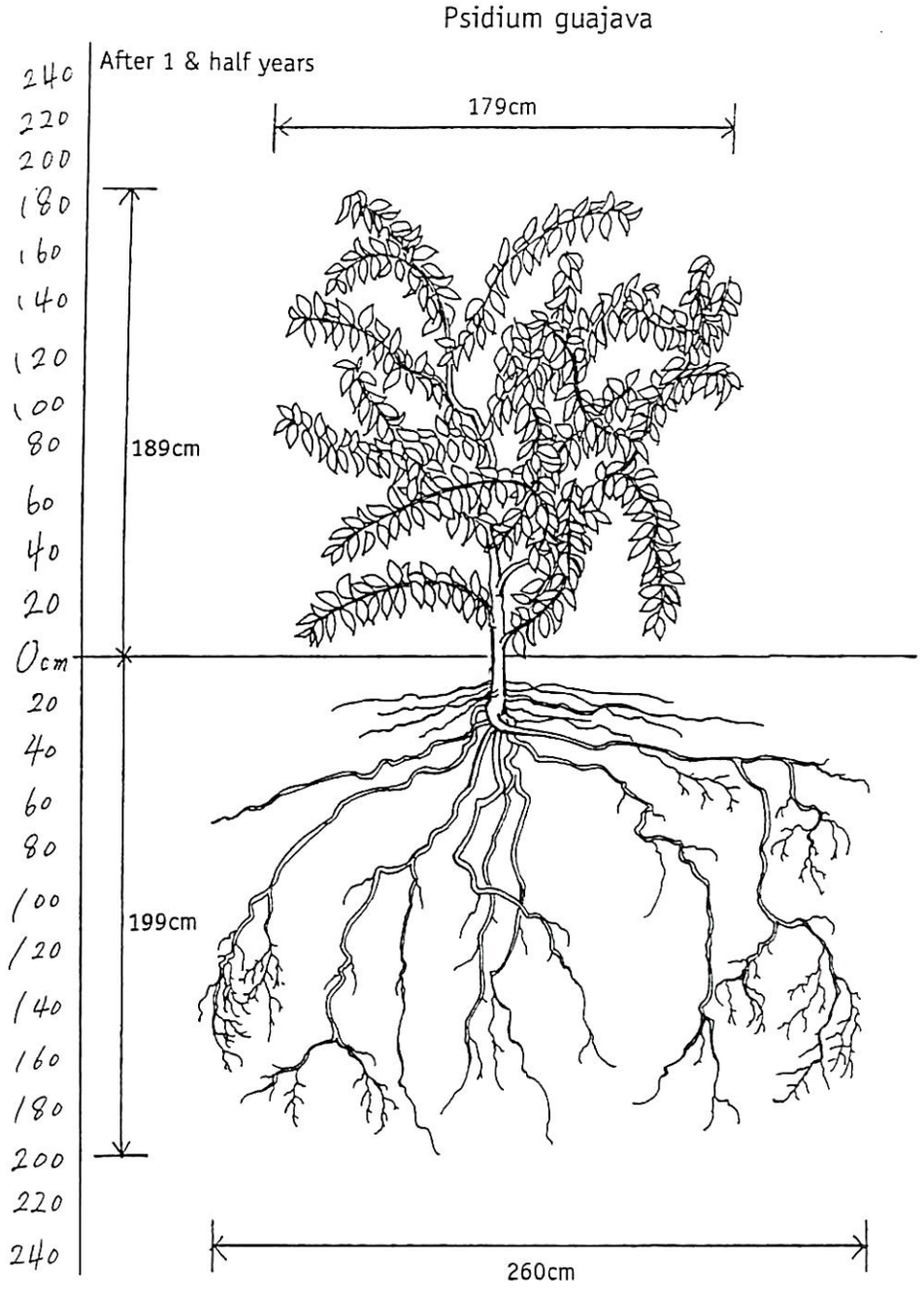


B-15) *Psidium guajava*

Psidium guajava

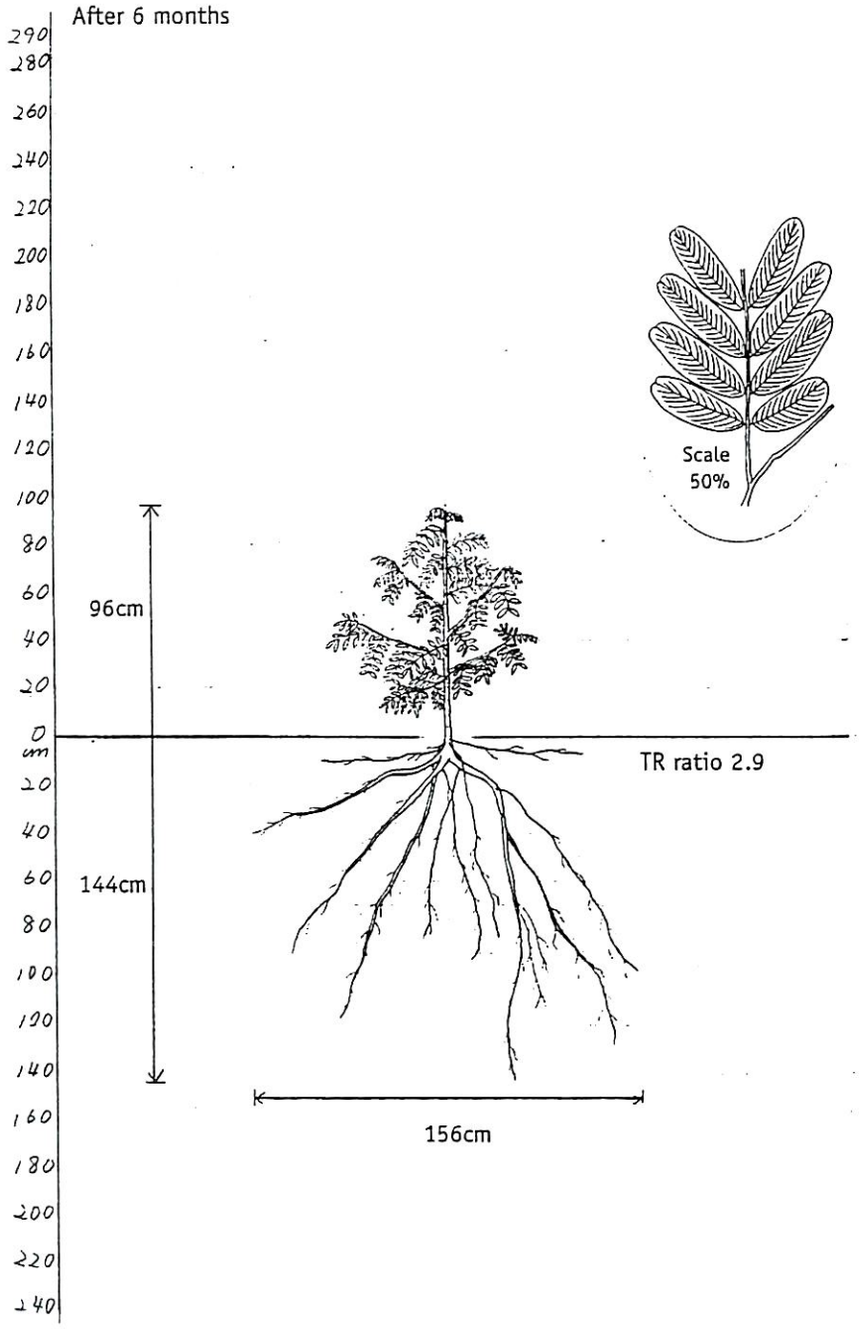


B-15) *Psidium guajava*



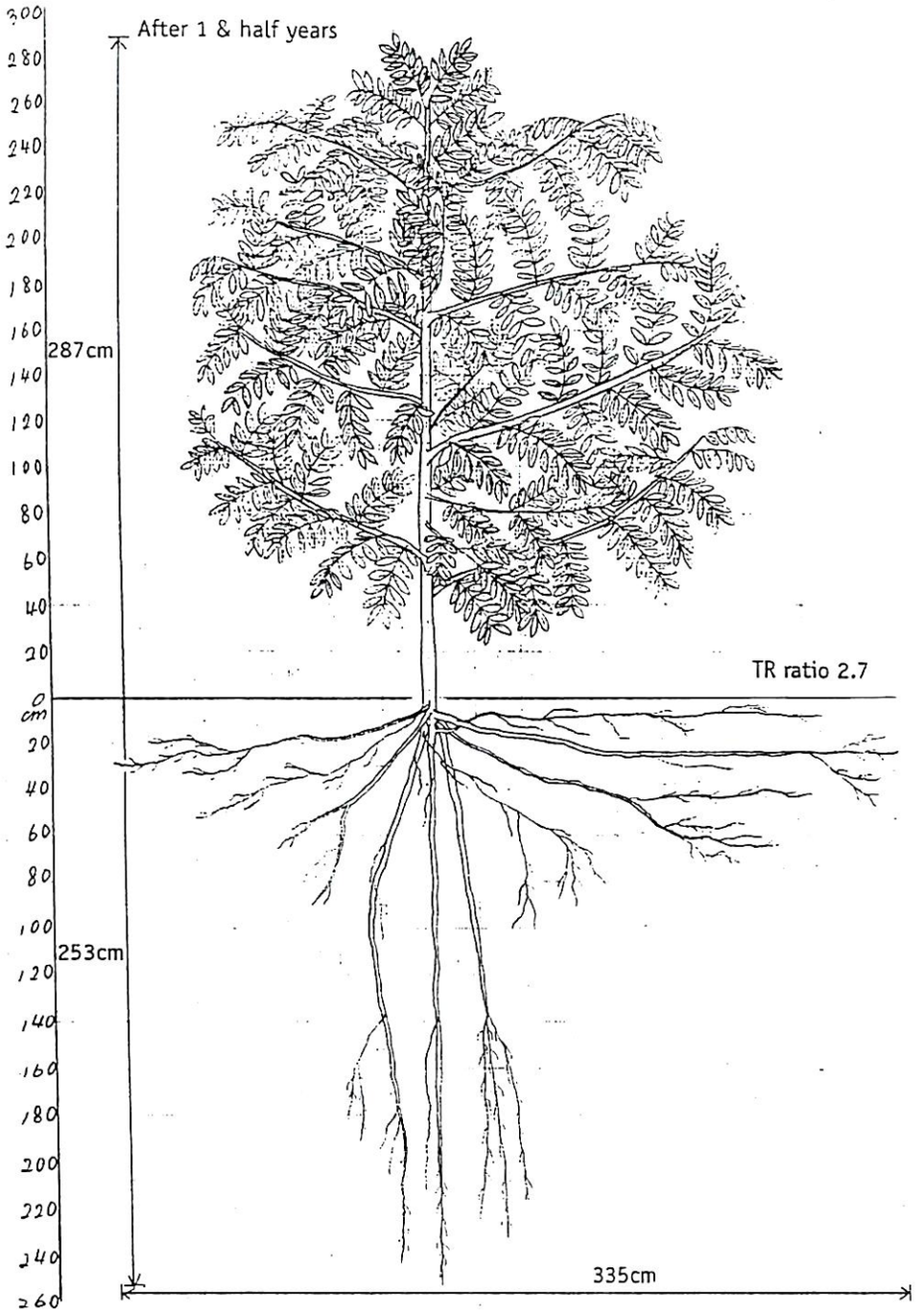
B-16) *Senna siamea*

Senna siamea



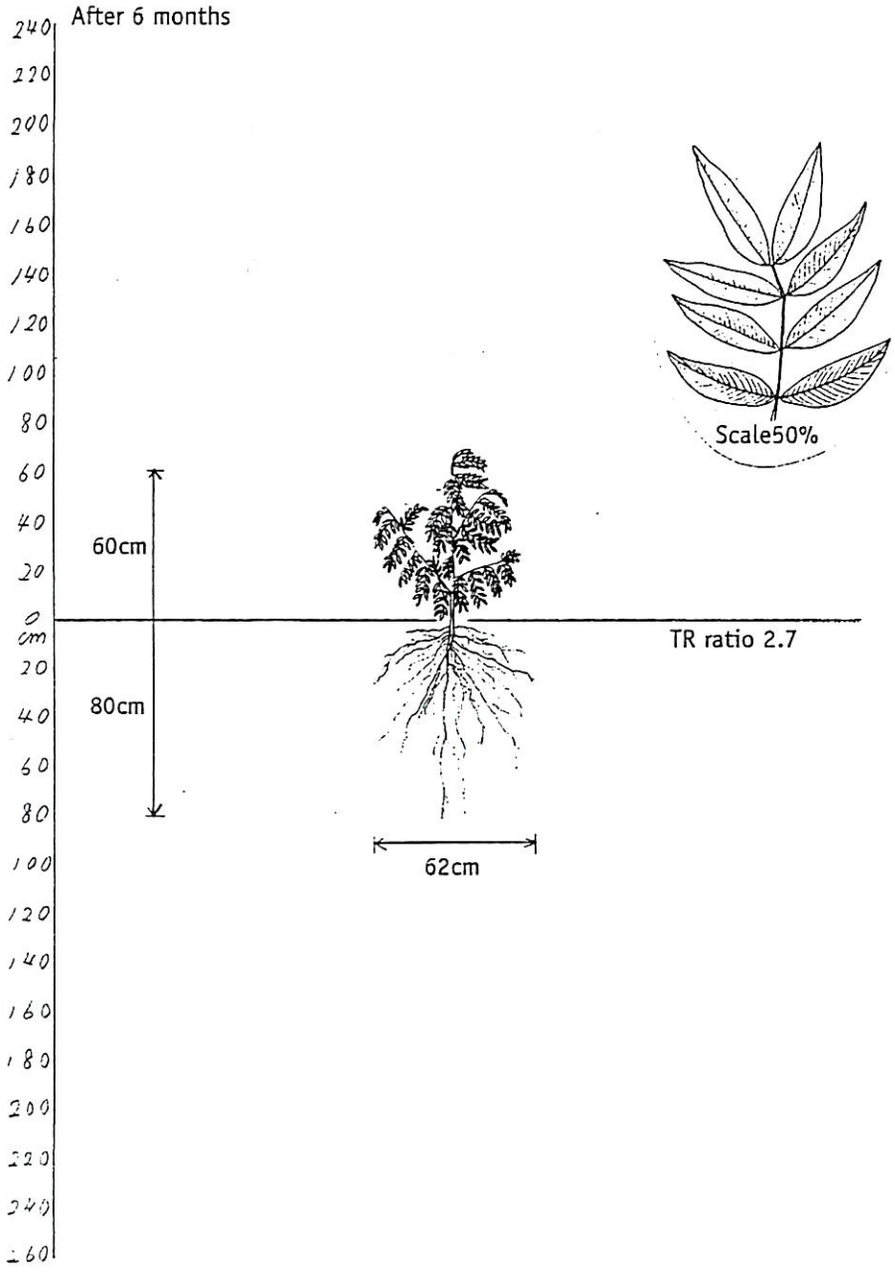
B-16) *Senna siamea*

Senna siamea



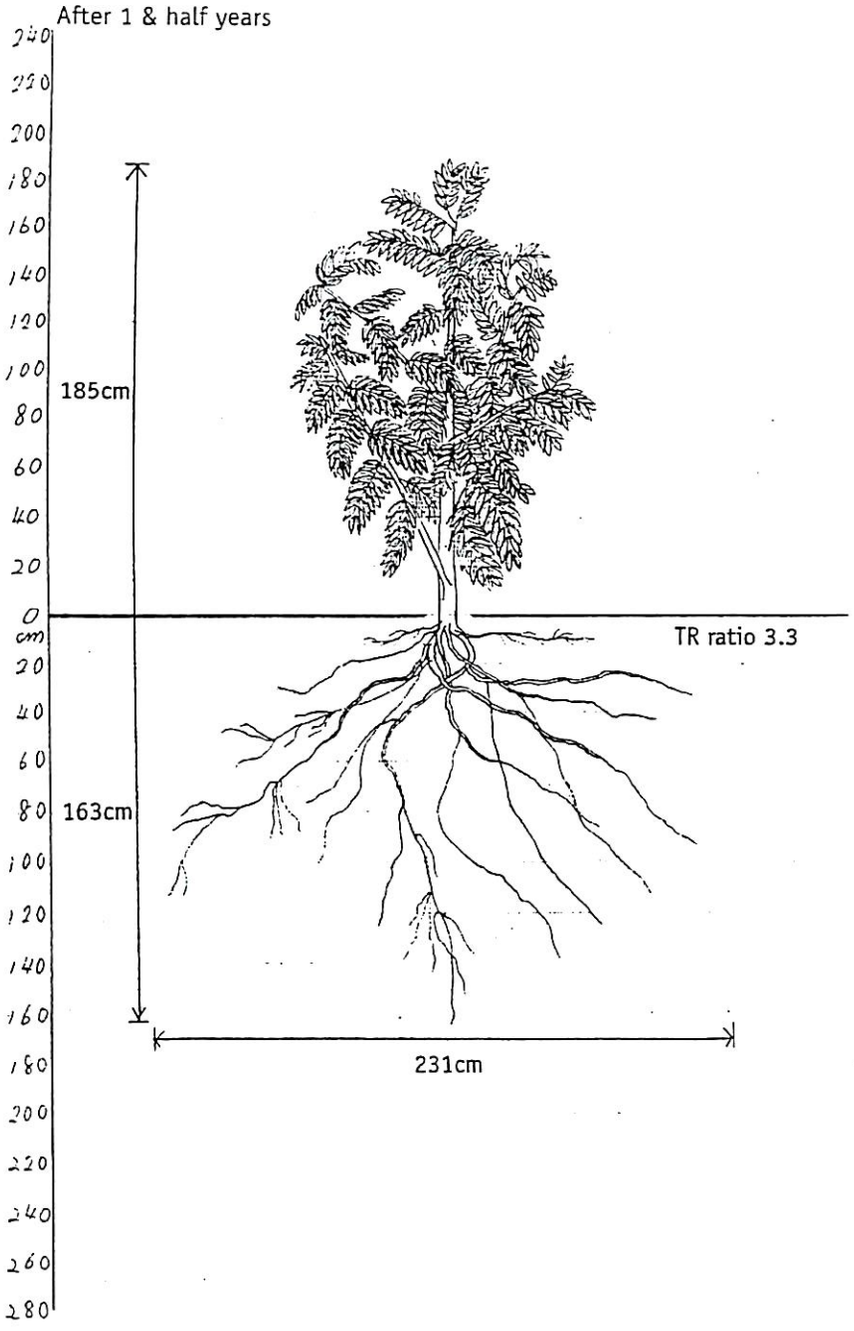
B-17) *Senna spectabilis*

Senna spectabilis



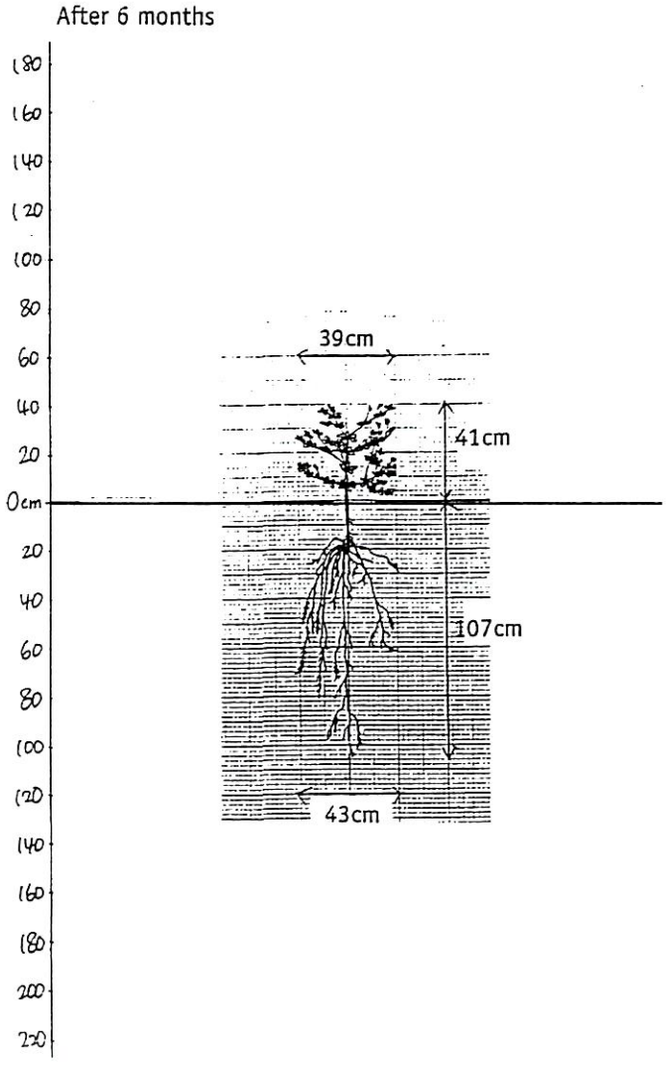
B-17) *Senna spectabilis*

Senna spectabilis



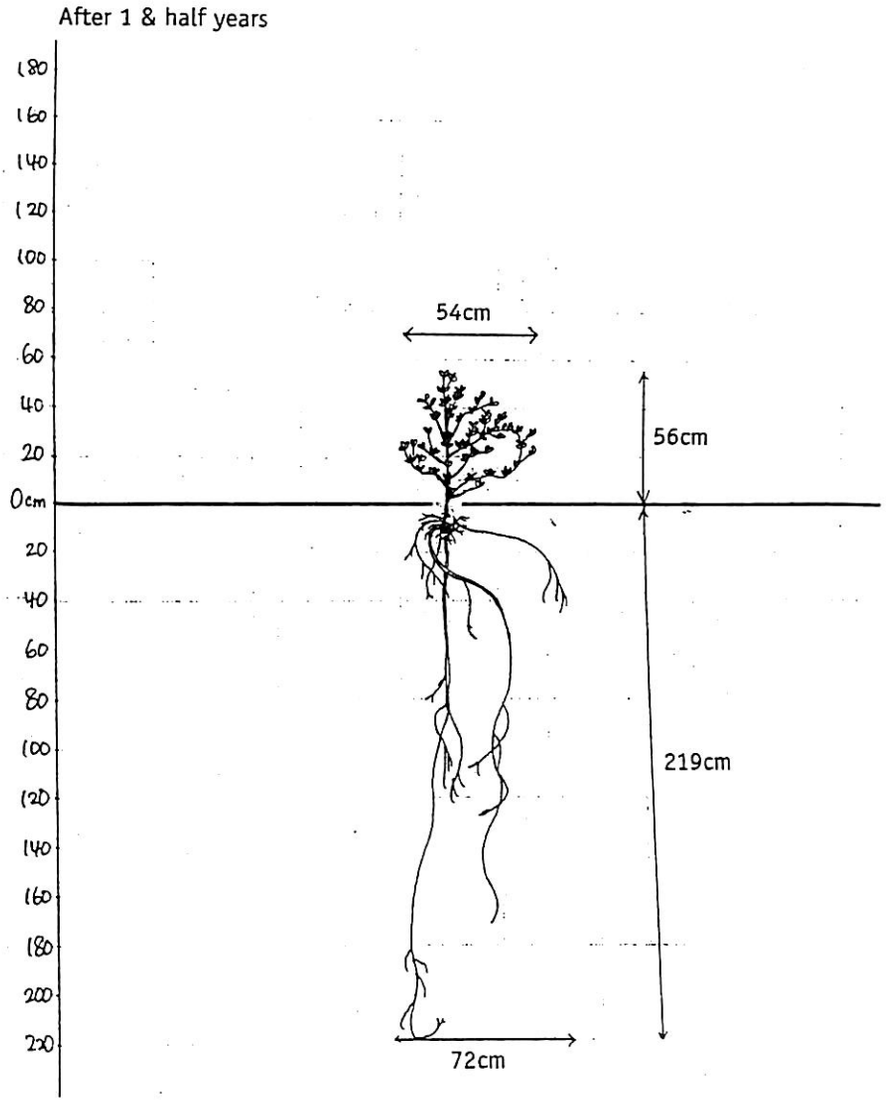
B-18) *Terminalia mentalis*

Terminalia mentalis



B-18) *Terminalia mentalis*

Terminalia mentalis



8. APPENDIX

Average value of measured items

1) six month after planted

Species	planted year	length (cm)				weight (g)					dry weight (g)			diameter (cm)	Number of main roots	Number of roots at			Number of branches	shoot width (cm)	root width (cm)	
		shoot	root	total length	shoot /root	shoot	main root	small root	root total	shoot /root	shoot	root	shoot /root			20cm depth	50cm depth	75cm depth				
Acacia auriculiformis	97	144	206	351	0.7	500	90	75	165	3.05	197	74	3.02	2.1	3	108	69	57	19	82	214	exotic
Acacia gerardii	94	49	143	192	0.35	42	10	13	23	1.75	20	11	1.78	0.9	4	12	8	6	9	50	64	
Acacia holosericea	95	84	136	220	0.64	443	27	51	78	5.31	161	34	4.45	1.4	4	68	52	23	8	81	140	exotic
Acacia melifera	94	41	154	195	0.27	27	6	12	18	1.51	15	10	1.44	0.9	4	14	6	5	12	43	43	
Acacia nilotica	93-94	49	126	175	0.41	60			35	1.61	30	19	1.63	1.2	4	19	14	7			84	
Acacia polyacantha	93	47	103	150	0.44	33			37	0.89	18	21	0.9	1.1	4	16	12	5			81	
Acacia senegal	95	73	178	251	0.42	86	21	41	62	1.39	40	25	1.61	1.1	4	34	15	13	25	81	78	
Acacia sieberiana	97	114	198	313	0.6	267	50	92	142	2.03	132	51	2.64	0.9	3	77	40	25	28	82	73	
Acacia tortilis	95	88	176	264	0.52	182	21	60	81	2.13	81	30	2.66	1.1	3	32	17	9	17	111	60	
Albizia anthelminitica	95	44	172	216	0.26	33	14	33	47	0.69	16	20	0.79	0.7	3	20	18	7	7	46	38	
Albizia lebbeck	96	93	136	228	0.68	135	43	80	123	1	62	56	1	1.2	3	32	20	12	2	56	70	exotic
Azadirachta indica	94	52	106	158	0.49	22	14	14	28	0.76	10	11	0.89	1	3	14	5	3	2	27	34	exotic
Balanites aegyptiaca	93	28	75	103	0.46	8			12	0.61	4	5	0.65	0.7	3	17	5	3			30	
Berchemia discolor	96	28	120	148	0.24	20	6	12	18	1.04	10	8	1.08	0.6	3	22	10	8	10	28	44	
Carica papaya	97	145	68	213	2.24	1513	600	388	988	1.53	260	212	1.24	5.4	2	53	38	16	0	97	275	exotic
Casuarina equisetifolia	94	105	87	192	1.23	75	11	11	22	3.63	29	9	3.38	1.1	3	17	16	15	14	30	57	exotic
Cordia ovalis	95	70	155	225	0.47	444	72	117	189	2.54	167	64	2.93	2	5	40	23	16	34	102	230	
Croton megalocarpus	93	46	75	121	0.64	24			11	2.14	13	7	1.94	0.7	4	17	29	6			57	
Dalbergia melanoxylon	93-94	34	100	135	0.34	17			25	0.66	8	12	0.75	0.8	5	18	14	7			47	
Dovyalis caffra	96	40	115	154	0.34	30	6	18	24	1.31	12	9	1.43	0.8	2	53	41	12	6	25	59	exotic
Eucaliptus paniculata	95	120	125	245	0.98	681	63	64	127	5.35	229	44	5.29	2	4	23	30	22	37	99	184	exotic
Faidherbia albida	95	69	177	245	0.39	48	13	50	63	0.75	22	28	0.81	0.7	3	19	9	7	33	51	47	
Grevillea robusta	95	89	101	189	0.92	183	19	22	42	4.54	75	19	4.01	1.4	4	51	28	4	10	56	65	exotic
Grewia aricantha	97	49	104	153	0.48	19	20	19	39	0.57	7	8	0.82	0.6	2	78	49	25	11	38	44	
Jacaranda mimosifolia	95	84	130	214	0.68	210	46	43	89	2.4	86	33	2.65	1.9	4	47	34	18	4	66	110	exotic
Leucaena leucocephala	95	91	141	232	0.65	87	42	34	76	1.08	32	30	1.04	1.4	4	37	24	8	10	46	76	exotic
Melia volkensii	93-94	67	81	148	0.85	144			168	0.75	34	31	0.95	1.7	4	11	7	4			84	
Moringa oleifera	96	67	69	135	1.05	76	52	33	85	0.95	20	19	1.17	1.2	3	12	4	3	2	50	59	exotic
Percea americana	97	97	91	188	1.07	309	69	63	131	2.26	92	55	1.59	2.1	3	61	61	16	6	55	110	exotic
Prosopis juliflora	93-94	49	118	168	0.44	31			15	2.12	17	8	2.14	0.8	5	16	11	7			67	exotic
Psidium guajava	97	102	107	209	0.97	144	28	50	78	1.83	65	40	1.64	1.4	2	225	229	168	5	54	107	exotic
Senna siamea	93-94	82	122	204	0.67	245			95	2.43	86	41	2.11	1.6	4	23	18	10			108	exotic
Senna spectabilis	93	50	80	130	0.63	49			16	2.71	23	8	2.42	1	4	26	19	4			62	exotic
Tamarindus indica	93	47	95	141	0.5	34			27	1.18	16	17	0.92	0.8	4	15	9	3			61	
Terminalia brownii	94	45	121	167	0.38	82	17	19	37	2.28	30	15	1.95	1.4	4	16	12	14	12	45	68	
Terminalia mentalis	96	41	107	148	0.4	26	5	8	13	1.93	12	6	1.9	0.8	2	47	35	14	7	39	43	exotic
Terminalia prunioides	96	30	152	181	0.19	22	4	12	16	1.37	11	9	1.28	0.6	2	34	22	21	18	27	31	
Vitex doniana	97	99	153	253	0.7	344	116	114	230	1.62	107	79	1.34	2.7	4	36	26	19	5	50	90	
Ziziphus mauritiana	97	68	188	257	0.36	188	50	75	125	1.78	90	42	2.05	1.7	3	30	27	22	15	111	78	

2) one year and a half after planted

Species	planted year	length (cm)				weight (g)					dry weight (g)			diameter	Number	Number of roots at			Number of	shoot	root	
		shoot	root	total length	shoot /root	shoot	main root	small root	root total	shoot /root	shoot	root	shoot /root	(cm)	of main roots	20cm depth	50cm depth	75cm depth	branches	width (cm)	width (cm)	
Acacia auriculiformis	97	366	270	636	1.55	13413	1888	2463	4350	3.09	7785	2650	2.94	7.5	4	364	202	192	45	281	470	exotic
Acacia gerardii	94	127	237	364	0.57	909	143	122	265	3.48	432	115	3.43	2.2	3	37	34	18	19	113	235	
Acacia holosericea	95	358	217	575	1.71	15244	1337	1379	2715	5.72	8283	1488	6.34	6.8	6	228	131	54	63	197	422	exotic
Acacia mellifera	94	58	221	279	0.26	150	50	49	98	1.4	67	48	1.33	1.3	3	24	11	13	37	74	94	
Acacia nilotica	93-94	133	210	343	0.64	814	131	203	334	2.47	387	187	2.06	2.7	6	32	26	16	32	130	220	
Acacia polyacantha	93	159	225	384	0.77	724	242	193	435	1.73	362	195	1.98	3	6	24	17	12	17	131	262	
Acacia senegal	95	173	254	427	0.71	3768	280	772	1051	3.07	1812	529	2.89	4	5	23	20	11	76	170	167	
Acacia sieberiana	97	180	214	394	0.89	2550	300	475	775	3.95	1115	409	2.9	3.9	4	34	21	14	51	210	130	
Acacia tortilis	95	234	275	509	0.91	2388	178	722	900	2.61	1359	448	2.87	3.2	4	22	16	17	49	159	318	
Albizia anthelmintica	95	83	260	343	0.32	241	60	171	231	1.05	154	113	1.35	1.6	2	16	17	10	19	98	90	
Albizia lebbeck	96	234	213	446	1.1	1125	669	631	1300	0.87	623	613	0.94	3.7	5	34	44	14	7	130	197	exotic
Azadirachta indica	94	173	169	343	1.07	1044	229	412	641	1.54	398	226	1.69	2.8	4	19	14	12	10	95	160	exotic
Balanites aegyptiaca	93	50	167	218	0.34	57	21	28	48	1.35	25	22	1.43	1	3	12	6	3	16	43	68	
Bauhemia discolor	96	81	143	224	0.64	84	59	96	155	0.73	40	56	1.04	1	3	22	9	8	17	63	65	
Carica papaya	97	152	227	379	0.67	2650	975	375	1350	1.96	532	214	2.49	7	4	50	52	16	0	118	280	exotic
Casuarina equisetifolia	94	251	172	422	1.45	1370	201	202	402	3.43	544	182	3.1	3	4	52	30	34	62	90	172	exotic
Cordia ovalis	95	183	338	521	0.59	6027	451	1034	1486	3.93	2208	681	3.06	4.5	7	53	35	31	65	212	603	
Croton megalocarpus	93	112	165	277	0.69	665	111	51	163	4.26	255	83	3.43	2.2	5	27	30	16	18	84	128	
Dalbergia melanoxylon	93-94	91	187	278	0.49	301	79	140	219	1.16	175	108	1.34	1.9	5	26	19	18	20	89	120	
Dovyalis caffra	96	90	229	318	0.38	150	32	66	97	1.34	52	37	1.19	1.4	2	29	79	36	10	48	107	exotic
Eucalyptus paniculata	95	365	248	613	1.48	13057	1606	1994	3599	3.68	6179	1791	3.38	7.5	6	48	34	34	48	198	536	exotic
Euphorbia albida	95	215	343	557	0.65	1425	187	595	782	1.45	593	401	1.23	2.7	3	17	9	8	55	131	141	
Grevillea robusta	95	348	181	529	2.01	8492	1296	884	2180	3.82	4604	1152	3.93	7.6	4	87	57	39	77	193	269	exotic
Jacaranda mimosifolia	95	306	270	577	1.18	6026	1890	2024	3915	1.54	3865	1840	2.1	8.3	6	45	65	24	12	139	316	exotic
Leucaena leucocephala	95	175	232	407	0.84	773	224	200	424	1.75	316	195	1.49	3.3	4	15	15	10	28	83	239	exotic
Melia volkensii	93-94	176	151	328	1.2	2644	471	1072	1544	2.06	792	421	2.39	4	5	16	15	9	15	144	221	
Moringa oleifera	96	216	145	361	1.39	1185	138	613	750	0.79	201	288	0.42	2.3	4	10	12	3	5	60	129	exotic
Persea americana	97	143	147	290	0.98	1588	225	150	375	4.33	689	181	3.91	3.3	3	66	36	20	18	120	161	exotic
Prosopis juliflora	93-94	135	202	338	0.66	351	52	76	128	2.59	158	61	2.46	1.8	3	18	17	11	19	122	215	exotic
Psidium guajava	97	189	163	352	1.18	3890	213	488	700	5.5	1347	393	3.43	3.6	6	93	109	84	30	179	297	exotic
Senna siamea	93-94	218	249	467	0.88	2901	814	692	1506	1.97	1384	506	2.66	4.2	7	34	25	21	18	200	273	exotic
Senna spectabilis	93	185	163	347	1.14	1056	188	145	333	3.34	372	157	2.31	3.1	6	30	28	18	9	92	231	exotic
Tamarindus indica	93	91	219	310	0.42	239	74	96	169	1.4	96	94	1.14	1.8	3	17	15	11	17	85	160	
Terminalia brownii	94	147	199	346	0.76	1166	191	384	575	1.97	533	269	1.89	3.6	4	28	37	25	20	136	242	
Terminalia mentalis	96	53	200	253	0.27	90	21	24	45	1.79	25	26	1.27	1.3	2	28	33	17	7	42	65	exotic
Terminalia prunioides	96	50	221	271	0.23	47	15	19	34	1.25	11	20	0.85	0.9	2	19	37	16	16	27	38	
Thevetia peruviana	97	100	173	273	0.58	1200	325	488	813	1.42	551	479	1.09	5.5	7	33	29	19	12	114	197	
Ziziphus mauritiana	97	275	335	610	0.85	6500	923	1450	2373	2.75	3228	1098	2.96	6.1	8	27	49	33	79	317	405	