THE EFFECTS OF ROOT SEVERANCE IN SAVANNA TREES IN NYLSVLEY NATURE RESERVE, LIMPOPO PROVINCE, SOUTH AFRICA

By

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DECLARATION

I, Mulaudzi Thilivhali Adelaide, declares that this dissertation is my original work and has not been submitted for any degree at any other university or institution. The research does not contain other person's writing unless specifically acknowledged and referenced accordingly.

Signed (Student): …………………………………… Date: 12/03/2022

DEDICATION

I dedicate this work to my family (husband and children), parents and siblings for without their support, this work was going to be impossible.

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My thanksgiving goes to the Almighty God for his grace. It was not an easy journey. I like to thank University of Venda Department of Botany for giving me opportunity to pursue my studies. I would also like to appreciate supervisors by the name of Mr. M.H Ligavha–Mbelengwa and Professor M.P Tshisikhawe for having heart for mentoring, supporting and assisting me with my study. Dr. K Magwede for all the inputs and support during my study.

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The Nylsvley Nature Reserve staff for permission and assistance in my research.

ABSTRACT

Root severance has effect on *Terminalia sericea* and *Burkea africana*. *Burkea africana* is a deciduous tree belonging to the family Fabaceae (Caesalpinioideae) while *Terminalia sericea* is a deciduous tree of the family Combretaceae. Savanna trees respond to root severance in different ways including producing root suckers.

Root suckering take place commonly following disturbance events such as fire, and root severance. The root suckers originate from primordia which are formed from meristematic cells in the cork cambium of the roots during secondary growth. The suckering of roots allows individuals spreading from the original establishment site, thereby promoting new sites colonization. Root suckering is affected by light, soil temperature, soil aeration, growth regulators, hormones, and root carbohydrates reserve.

The study site was located subjectively in an area dominated by the species under study. Twenty juvenile and adult trees of the two species were selected where one lateral root was cut. The data collected in each selected species are basal stem diameter of trees, tree crown, and tree height; direction of root cut; number of root suckers produced; root sucker diameter and height of the trees.

The result shows that root severance by producing root suckers as observed in *Burkea africana* and *Terminalia sericea*. More distal root suckers were produced than proximal root suckers. The health of the plant is not affected by either severing root or development of root suckers. The growth or vigour of root suckers depends on the parent root system, where they are initiated, micro environmental conditions such as soil temperature and herbivory. Juvenile plants produced more root suckers

compared to adult plants of *Burkea africana*. *Burkea africana* responded quickly but *Terminalia sericea* needs more time to develop root suckers.

Therefore, the knowledge of root sucker and root severance of the two species (i.e. *Terminalia sericea* and *Burkea africana*) in this study may contribute to the conservation and management recommendation of the population of the species.

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LIST OF ACRONYMS

A: Adult plants

A: August 2021

B. Africana: *Burkea africana*

B: *Burkea africana*

BJAN: Proximal root sucker (produced by root connected to the plant) of *B. africana* juvenile plant in November 2021.

J: Juvenile plants.

M: March 2021

N: November 2021

NNR: Nylsvley Nature Reserve

RS: Total number of root sucker

RSA: Proximal root sucker (produced by root still connected to the plant)

RSAA: Distal root sucker produced by adult plants in August 2021.

RSAM: Distal root sucker produced by adult plants in March 2021.

RSAN: Distal root sucker produced by adult plants in November 2021.

RSB: Distal root suckers (produced by root no longer disconnected to the plant).

RSBA: Distal root sucker produced by *B. africana* adult plants.

RSBJ: Distal root sucker produced by *Burkea africana* juvenile plants.

RSBJA: Proximal root sucker (root sucker produced by roots connected to the plant) of *Burkea africana* juvenile plants

RSJA: Distal root sucker produced by juvenile plants in August 2021.

RSJM: Distal root sucker produced by juvenile plants in March 2021.

RSJN: Distal root sucker produced by juvenile plants in November 2021.

RSTA: Distal root sucker produced by *T. sericea* adult plants.

RSTJ: Distal root sucker produced by *Terminalia sericea*.

T. sericea: *Terminalia sericea*

T: *Terminalia sericea (T. sericea)*.

TRS: Total number of root sucker

CHAPTER ONE

INTRODUCTION

1.1 Background of the study

Root systems are very important in the tree stability (Smiley, 2008). The important role played by roots is anchoring the plants in the soils to ensure stability against forces of nature such as wind (Gregory, 2008). Tree anchorage depends on the morphology of root system as well as soil type (Ennos 1993; Stokes, 1999; Stokes and Mattheck 1996). The first structure that emerges after seed germination is the roots. Roots enable the seedling to become anchored in the soil and absorb water and nutrients needed for survival (Raven *et al*., 2005). The tree stability loss is usually related to an alteration in the architecture of system of the root (Strong and La Roi, 1983).

The important growth of root system is a combination of the following factors: the growth conditions of stem determine which type and what quantity of wood is formed in the root (Hamilton, 1989). The growth of stem determines location of root part or root. Roots which are near the trees base have greater growth than roots which are further out. The stored carbohydrate (food) is used mainly for growth in roots. A large number of reserves must be stored in order for root growth to occur in the root. The radial growth of roots starts after "food" reserves in existing woody roots are stored (Hamilton, 1989). There is a delay in recovery of root growth and slower growth of shoots if food reserves are depleted and there is a delay in their replenishment (Hamilton, 1989).

It is clear that all conditions are interdependent, i.e., the leaves, stems, and roots conditions. The roots have function which are more important of food reserves accumulation for top growth which the canopy can be affected (Hamilton, 1989). The leaf canopy can be stressed by a delay in pruning of root recovery. If the storage of food reserves in the roots have not been done, it causes a delay in root enlargement. The vigour of a tree can be retained if the concentration of roots is present near the tree base even when pruning of root may be too close to the tree trunk. There is enhancement of chances for recovery which is acceptable and performance in general if carbohydrate reserves are high. It is important to make sure there is large amount of carbohydrate reserves before removing the root (Hamilton, 1989).

The tree stability and health may be reduced when roots are decayed, cut, or damaged (Hamilton, 1989). The growth of a tree (Pretzsch *et al*., 2016) and vitality (Watson, 1998) are reduced, and the processes of physiology are altered (Benson *et al*., 2019a) in addition to affecting the stability of tree negatively (Smiley *et al*., 2014) when roots are removed from the tree. Tree health can be seriously affected by severing roots. Severing roots affects the carbohydrate storage, hydraulic architecture, and hormone balance of the plant, which is the physiology of the plant (Jackson *et al*., 2000).

The morphology of the system of the roots is a function of characteristics of a species and conditions of the soil. The main function is solute and water transportation from the soil to the leaves and shoots (Tyree, 2003). The absorption of water and dissolved soil minerals is facilitated by fine fibrous roots and root hairs. Roots play important roles in the growth of tree and photosynthesis (Hamilton, 1989; Day *et al*., 2010). The growth of roots is affected indirectly by the stress of the tree through the influence which is unfavourable on the process of photosynthesis. The amount of available carbohydrates to be used by the roots and stored is reduced by stress (Hamilton, 1989).

The surface area of roots is effectively increased by the relationship that is symbiotic between mycorrhizae and fine roots which have contact with soil. This make the trees to be able to increase the absorption of mineral ion and water (Rosling and Sveriges, 2009). The ability of this relationship to increase an insoluble phosphorous availability, which is usually an unavailable in a form that is usable, is of particular importance. Mycorrhizae can change the form of phosphorus which is insoluble into a form which is soluble thereby making it ready to be easily absorbed by the roots (Watson,1998).

The effects range which are negative and positive are elicited by severing roots from trees. The removal of roots negatively affects the root to shoot ratio (Benson *et al.*, 2019b). Plants generally respond to roots removal by enhancing the growth of root and suppressing the growth of the shoot to re-establish the balance (DesRochers and Tremblay, 2009; Sudmeyer *et al*., 2004). The height of a tree can be used in trees that are young to measure the growth of the shoot. Even though the effect varies, removal of roots also negatively affects the growth of shoot in the growing season following the pruning of root (Autio and Greene, 1994; Dong *et al*., 2016; Ferree, 1989; Fini *et al*., 2013; Watson, 1998; Young and Werner, 1982).

It may also depend on the tree's ability for the restoration of the ratio of root to shoot, age of the tree and root loss extent. Plant needs to grow new roots to recover from root pruning injury and restoration of ratio of root to shoot (Benson *et al.,* 2019b). This represses shoot growth due to photo assimilates preferential allocation to the roots (Hamilton, 1989). Although the response varies between species and may be influenced positively when available moisture of the soil is 35% low of field capacity (Dong *et al*., 2016), when water becomes a limiting resource (Benson *et al*., 2019a), new biomass of root may increase when pruning intensity increases (Farmer and Pezeshki, 2004).

Investigation on the effects of root loss on nursery production, stability of tree, growth, and recently using modern analytical equipment on processes of plant physiology has been done with species of tree in a narrow range (Benson *et al*., 2019b). However, loss of root effects extensive research is still needed (Costello *et al*., 2017). The study area used in this study is Nylsvley Nature Reserve. Savanna trees used for this research are: *Burkea africana*, and *Terminalia sericea*.

1.2 Description of the species under study

1.2.1 *Terminalia sericea Burch. ex* DC

Terminalia sericea is deciduous tree belonging to Combretaceae family. The *Terminalia* name was from the Latin *terminus* referring to leaves that are found at the shoots very tip. The species *sericea* in Latin that means silky referring to the dense silky hairs found on the leaves. It is known and called in different languages as “Monakanakane” or “Mososo” amongst the Sotho tribes, “Mogonono” in Tswana, Ämangwe” in Zulu, “Vaalboom” in Afrikaans, “Mangwe” in Ndebele and “Silver cluster leaf” in English (Van Wyk *et al*., 2005).

Terminalia sericea is a species which is small to medium sized (Coates-Palgrave, 2002). It grows as a single stemmed tree when not coppicing reaching the height of 9 m, but individual trees can reach height of 23 cm or a multi-stemmed shrub which is 4-6 m tall (Coates-Palgrave, 2002). It has a rounded, flattish crown (Mongalo *et al*., 2016) and horizontal branches (Coates-Palgrave, 2002). It has erect stem and wood which is hard and yellow. The dark grey or brownish bark is deeply vertically fissured with ridges splitting and joining (Coates-Palgrave, 2002).

The leaves with smooth margins, silvery, hairy and crowded near the branch are narrowly obovate-elliptic. The cream flowers (see figure 1A below) have smell which is unpleasant (Van Wyk and Gericke, 2007). *T. sericea* fruit turns to darker pink colour as it ripens (Mongalo *et al*., 2016) and when drying is reddish brown as in figure 1B below. It is surrounded by a wing, containing one seed (Van Wyk and van Wyk, 1997). Seeds may be attached for a period of a year to the branch and wind dispersed. A brownish coat covered the seeds which may be hard to open (Mongalo *et al*., 2016). It germinates readily from fresh healthy seeds (Coates-Palgrave, 2002).

It occurs in tropical and subtropical regions and plateau. *T. sericea* a common species found from Tanzania and the Democratic Republic of Congo, southwards to Angola, Namibia, Zimbabwe, Botswana, and South Africa in savannas which are dystrophic (Coates-Palgrave, 2002). The species is also common in the lowveld, bush and bushveld savanna vegetation types of South Africa (Moyo *et al*., 2015), almost invariably on sandy soils, often at vlei margins (Walker *et al*., 1986) and in stand which are dense (Van Wyk and Van Wyk, 1997).

In South Africa, it is available in the wild in abundance (Tshisikhawe *et al*., 2012; Banda *et al*., 2008). It is not one of threatened plant on the list of Red Data (Raimondo *et al*., 2009). It is facing severe harvesting pressure in Zimbabwe due to its uses (Maroyi, 2012). In Mpumalanga Province, South Africa the species is one of the top ten most plants traded as firewood and medicine (Dold and Cocks, 2002).

A B

Figure 1.1: *Terminalia sericea* during flowering (A) and seeds (B)

1.2.2 *Burkea africana* Hook.

Burkea africana (in figure 3.3) a deciduous tree belonging to Fabaceae (Caesalpinioideae) family (Coates-Palgrave, 2002). The *Burkea* name is derived from Joseph Burke's surname known as the famous collector who collected plants in the 1840s in Magaliesberg. The continent of Africa is where the species is distributed widely, the reason why the name *africana* (Tanko *et al*., 2011). *Burkea* is a genus which is monotypic as is comprised of one species only (Van Wyk and Van Wyk, 1997). *Burkea africana* is known and called in different languages in English is "wild syringa", “seringa tree”, as well as “Rhodesian ash” or in Tsonga “mpulu”, “monato” in Tswana, in Venda “mufhulu”, and “wildesering” Afrikaans (Mair *et al*., 2018; Magwede, 2019).

Figure 1.2: *Burkea africana* tree in Nylsvley Nature Reserve.

Burkea africana, a tree which is medium sized and mostly eight to ten meters tall and reach height of twenty meters (Coates-Palgrave, 2002). It has a flat-top and spreading crown (Van Wyk and Van Wyk, 1997) and grows up to 61 cm in diameter (Fanshawe, 1972). The bark appears dark grey, rough, and flaking. The leaves are alternate and paripinnate with opposite leaflets clustered at the tip of shoots. Flowers are creamy-white and produced with the new leaves in drooping spikes (Van Wyk and Van Wyk, 1997). *Burkea africana* has separate female and male plants meaning that is dioecious. It produces seeds cohort annually (Nemadodzi, 2018). Seeds remain for a very long period on the tree (Coates-Palgrave, 2002). Seeds germination is poor, grows slowly and has the resistance to frost and fire is low (Van Wyk, 1972).

A study was conducted by Witkowski (unpublished data) between 1978 – 1999 in Nylsvley Game Reserve, revealed that most *Burkea africana* trees did not produce fruit each year but were above minimum size for fruiting. One percentage of reproductive trees were still having pods of seeds from last season and without flower in season to follow (Nemadodzi, 2018).

Burkea africana is one of many savannah plants that germinate cryptogeally. This type of germination evolved because of frequent burning (Jackson, 1974). It buries plumule in the soil and emanates from growth below the soil surface on the crown of the root and buds as to protection from frost and fire. The buds are bearded by the true stem part underground in the scale leaves axils which are protected. Buds give rise to new shoots after damage or burning of shoots which are above the ground (Walker *et al*., 1986; Wilson and Witkowski, 2003).

Burkea africana is widely spread in South Africa, tropical Africa, Sudan, Chad, Tanzania, Cameroon, Uganda, Ghana, Mali, Guinea, Niger, Senegal, Nigeria, Togo, Mozambique, Malawi, Zambia, Zimbabwe, Namibia, and Botswana (Tanko *et al*., 2011). The tree is predominant in Limpopo, Mpumalanga, and other parts of Gauteng Province in South Africa (Nemadodzi, 2018). In dry deciduous bush veld and woodlands, it is used to identify soils that are deep sandy (Wilson and Witkowski, 2003) and vary in depth from one to three meters. It is not listed as one of the threatened plant species in the Red Data, South Africa (Raimondo *et al*., 2009) but facing harvesting pressure due to its use in Zimbabwe (Maroyi, 2012).

1.3 Rationale (Problem statement)

To establish the other way of how the population of the species could be multiplied in savanna ecosystem. Species found in savanna ecosystem are exposed to frequent disturbances, such as fire, herbivory (Wakeling and Bond, 2007). Many woody species are surviving, and their population densities are increasing due to their ability to resprout from the lignotubers and other underground tissues (Bond and Midgley, 2001; Roques *et al*., 2001). Lignotubers are the large woody underground swellings. In Africa, they are documented (Bond and Midgley, 2003; Bond and Midgley, 2001; Huntley and Walker, 1982; and Lawson *et al*., 1968).

Another way of increasing population is through root suckering which allows vegetative spread of genet as another form of vegetative sprouting. Woody species that produce root suckering as compared to sprouting occurring from underground stumps and herbaceous species, and they are rare (Del Tredici, 2001; Lawson *et al*., 1968). The response of root suckering species to types of disturbances has been seldom studied (Wakeling and Bond, 2007). The root suckering ability of *Burkea africana* and *Terminalia sericea* found in savanna ecosystem has not been well documented.

1.4 Justification of the study

Past few years, the questions about tree roots such as problems of pest, breaking of sidewalk-curb and some relating to where and how they grow have been dealt with. However, the effect of root severance has not been dealt with in some tree species. However, the significant effects of root severance and guidelines for management

(Hamilton, 1989) remains a question to be answered.

The abundance of trees in disturbance-prone environments such as savannas, depend on the resprouting ability of the savanna tree species. The ability of plant to resprout can have impact that is major on the recovery and re- establishment of the tree. This reduces dependency of ecosystem on germination and production of seed for growth and maintenance of population. Seed production is not a means that is reliable for population maintenance and growth especially in ecosystem prone to disturbances (Bond and Midgley, 2001). It is because tree may be disturbed before sufficiently recovered for seed setting and as a result, it would have to reproduce asexually (Wakeling and Bond, 2007).

Terminalia sericea and *Burkea africana* were chosen as study species because they can resprout vegetatively after disturbances. The fact that they produce root suckers after root severance has not been widely recognized. Most studies on root suckering have been done on aspen (Farmer, 1962; Steineker, 1974, Baret and DesRochers, 2011; Jean *et al*., 2019) and few savanna trees like *Dichrostachys cinerea* (Wakeling and Bond, 2007). The more knowledge of their root suckering production capacity can contribute to the management recommendations.

1.5 Aim and objectives

The main aim of the study is to determine the effects of root severance in *Terminalia sericea* and *Burkea africana*. The following objectives were investigated:

i to investigate whether root severance results in the production of root suckers.

ii to investigate growth or vigor of the root suckers.

iii to investigate whether root suckers affect health of the plant.

iv to establish plant age at which root suckers are formed.

1.6 Hypothesis

Savanna ecosystems are strongly affected by fire, herbivory, and other disturbance agents (Scholes and Walker, 1993). Plants which are found in the savanna ecosystem have different mechanisms of survival. The hypothesis is that severance of savanna plant roots will result in the production of root suckers.

CHAPTER 2

LITERATURE REVIEW

2.1 Plant response to root severance

The response of plants to damage depends on the phenological condition of the plant at the time of damage (Menke and Trlica, 1981). The responses of plant to cutting of root are complex and include many aspects like nutrient and water status, changes in levels of hormones (e.g., abscisic acid and cytokinins), and processes of gas exchange, resulting in changes in the patterns of allocation of biomass and growth (Wang *et al*., 2014). The availabilities of plant nitrogen and water are not always affected negatively by a partial loss of root due to compensatory mechanisms (Wang *et al*., 2014).

Tree stability can be negatively affected when structural roots are severed, which can lead to trees to be uprooted by wind (Hamilton, 1989; Ghani *et al*., 2009; Smiley, 2008; Smiley *et al*., 2014). In addition, removal of roots put limitations on the ability to uptake minerals and water by trees (Jim, 2003), causing morphological and physiological stress. The plant responses to root excision morphological by overall vitality general reductions, dieback of canopy and shedding of leaf prematurely (Benson *et al*., 2018; Watson, 1998), growth which is reduced (Pretzsch *et al*., 2016; Ferree *et al*., 1989). The following are physiological plant responses to root cutting: reduction in photosynthesis, reduction in transpiration because closing of stomatal apertures, leaf-level carbon gains reduction, and damage of photo-oxidative (Benson *et al*., 2018; Fini *et al*., 2013; Dong *et al*., 2016; Wang *et al*., 2014). With the sufficient stored carbohydrate supply, trees can be able to keep vigour and recuperate from such injuries of removal of root (Hamilton, 1989).

The responses to root severance can be related to the degree of cutting of root (Ferree *et al*. 1989). Some of mechanics to survive in supply of nutrient and water capacities reduction caused by loss of root is promoting activity of physiology of roots left or renewal and restoration of the system of the root (Sudmeyer *et al*., 2004; Geisler and Ferree, 1984). But the responses in different species to cutting of root may differ when other factors and root removal interact (Sudmeyer *et al*., 2004).

2.2 Survival of plants in the savanna ecosystem

Approximately 40% of Africa is covered by tropical savannas (Scholes and Walker, 1993). In southern Africa savanna ecosystem is an important element (Scholes and Walker, 1993). This ecosystem is identified by the harmonious co-existence of grasses, trees (Higgins *et al*., 2000) and forbs (Trollope *et al*., 1989) under natural settings and several models have been developed to explain this coexistence (Higgins *et al*., 2000). Earlier studies (Walker *et al*., 1981; Scholes and Walker, 1993; Ward *et al*., 2013) argued that this coexistence is because of a natural regulating mechanism of vertical root niche partitioning. The shrubs develop deeper root systems to tap water from the ground- water aquifer while grasses extract water from the shallow soil subsurface creating an equilibrium co-exist (Nakanyala and Hipondoka, 2020).

Savanna ecosystem has seasonal rainfall of around 350 mm to 1800 mm per year. Consequently, there are seasons which takes about 3 to 8 months which are dry and warm (Scholes and Archer, 1997). Savanna trees have capability to grow in the environment of long drought condition. Savanna trees possess tap roots which are long and can reach water that are deep and leaves that drop in winter in order to reduce water loss through transpiration (Cole, 1986).

Woody species need several adaptations to survive in this environment. The most important factor in savanna ecosystem is the ability to tolerate frequent fire. Woody species found in savanna have developed some traits to survive and tolerate frequent fires. They need to have capability of resprouting when there is crown fire. Savanna trees have essential reserves of starch underground, and resprouting ability from crown, stem or base to achieve that (Bond and Midgley, 2001). They may use reserve of starch underground for the main stem very quick growth, thereby facilitating escape from the firetrap (Schutz *et al*., 2009).

Many woody species regenerate vegetatively mainly by root suckers and basal shoots (Skoglund, 1992). temperature, soil aeration, growth regulators, hormones, and root carbohydrates reserve. The suckering of root allows individuals to spread from their establishment site of origin and this promote new sites colonization as it promotes vegetative propagation (Bond and Midgley, 2003; Del Tredici, 2001). Seed production is not a reliable means of population maintenance and growth especially in ecosystem prone to disturbances (Bond and Midgley, 2001). It is because tree may be disturbed before recovering sufficiently to set seeds (Wakeling and Bond, 2007).

Root suckering is when the daughter ramets are produced from buds of the root, that is clonal growth form. It takes place in most herbaceous plants but few in woody plants (Jenik, 1994). Species producing root sucker compared with those that sprout from stumps underground are rare (Lawson *et al.*, 1968). In temperate broad-leaved woodlands is the best form in woody plants of clonal growth (Jenik, 1994).

2.3 Root sucker initiation

Root suckering commonly occurs after disturbance like fire (Frey *et al*., 2003). It can also take place when disturbance is absence. This result in multi age classes which are identical genetically, within a single clone (Kurze *et al*., 2007). The root suckers arise from primordia which is formed from meristematic cells in the cork cambium of the roots during secondary growth (Schier, 1973a). Sucker primordia are many. They can be in different growing stages which are primordia, fully matured concealed buds, or short shoots (Schier, 1973a). The restrained buds or short shoots are not in control of most suckering that occurs following disturbance, but newly initiated meristems and pre-existing primordia are. The growth of suckering arising from the other two sources tend to be more vigorous than that of suppressed buds (Sandberg, 1951; Schier, 1973a).

2.4 Factors affecting root suckering

The apical dominance effect of the tree crowns inhibited root sucker initiation in aspen (Steneker, 1974). The activity of hormones auxin and cytokinin is the one that mediated the condition of apical dominance (Frey *et al*., 2003). This apical dominance effect needs to be broken so that increased soil temperature will promote suckering (Steneker, 1974). Auxin is manufactured in the tissues that are aboveground and the phloem transport it to the roots (Frey *et al.,* 2003). It inhibits initiation of sucker bud (Eliasson, 1971; Schier, 1972) and promote the growth of root (Hicks, 1972). The hormone which is manufactured in the tips of growing root that are active is cytokinin. They show polar movement to the stem from the tips of root. They are known to counteract auxin activity (Hicks, 1972). It is very important in shoot development initiation in many plants' roots (Peterson, 1975; Schier, 1981).

The growth regulators gibberellic acid and abscisic acid (ABA) and may be involved in suckering. Abscisic acid ensures that sucker buds do not produce new shoots when trees are disturbed late in season until the next spring (Schier, 1973a) as inhibitor of sucker development (Schier *et al*., 1985). Gibberellic acid acts contrary to abscisic acid. It promotes the production of new shoot in the bud and sucker elongation when the apical dominance is out. However, primordia development is inhibited by high levels of gibberellic acid (Schier, 1973b) where root sucker originated from.

Temperature is important in determining early sucker development (Frey *et al*., 2003). The earlier initiation of suckers is stimulated by higher soil temperatures (Maini and Horton, 1966; Fraser *et al*., 2002). This promotes early emergence of suckers through the surface of soil (Zasada and Schier, 1973). This will provide growth season which is longer for earlier sucker initiated. As a result, temperatures that are warmer may take part in improving more establishment of sucker through survival and growth improvement, than enhancing initiation of total sucker (Frey *et al*., 2003).

Root carbohydrates reserves are essential in the growth of early sucker in the development when it is still dependent as photosystem is not yet fully functional (Frey *et al*., 2003). There is a strong correlation between sucker growth and total non-structural carbohydrates of the roots (Landhäusser and Lieffers, 2002; Schier and Zasada, 1973).

2.5 Examples of plants producing root suckers

Suckering of root was seen in most African savanna trees, in West Africa in plants like *Daniellia oliveri*, *Milletia thonningii*, *Parinari curatellifolia* and *Detarium microcarpum*, (Jenik, 1994; Lawson *et al*, 1968); *Lophira lanceolate* Van Tiegh.ex Keay (Ochnaceae) in Central Africa (Fawa *et al*., 2014); in Southern Africa *Spirostachys africana* and *Maytenus senegalensis. Dichrostachys glomerata* (Caesalpiniaceae) because of its suckering ability, has become invasive in Cuba (Jenik, 1994). Bond and Midgley (2003) have found few plants of the Genus Cliffortia (Rosaceae) in the Fynbos of the Southwestern Cape to produce root sucker.

Another species in southern African savannas was identified as one of the invasive is *Dichrostachys cinerea* (Leguminosae: Mimosoideae) (Roques *et al*., 2001; Hoffmann *et al*., 1999). The population densities of this species have in many areas over the last few decades increased greatly though it is native in the region due to its ability to form root suckers (Wakeling and Bond, 2007).

CHAPTER 3

STUDY AREA, MATERIALS AND METHODS

3.1. Description of the study area

3.1.1. Locality

The study was conducted in Nylsvley Nature Reserve in Limpopo, South Africa.

The Nylsvley Nature Reserve covers 3120 ha of mixed Bushveld (Acocks, 1953) and it lies on a flat to gently undulating plain between 1080 and 1140 m.a.s.l. It is comprised of Nylsvley 560 KR farm which is located on the Springbok flats. It is in South Africa in the province of Limpopo situated 10 km south of Mookgophong (24°36'- 24°42'S, 28°40'-28°44'E). There are Maroelakop (1140m) in the south-west, and Stemmerskop (1090m) slightly west of the former hills that prominently featured.

Nyl river bisected the area and flows along a shallow valley from south-west to north-east.

3.1.2. Vegetation

The Nylsvley Nature Reserve is a semi-arid savanna (Rutherford *et al*. 2006). The main vegetation type is dominated by *Burkea africana* (Hook.). It is a mixed, broadleaf deciduous savanna covered by 30% canopy of woody species (Walker *et al*., 1986). The vegetation type within the savanna biome is classified as central sandy bushveld (Rutherford *et al*., 2006). In southern Africa, 46% of all landscapes is covered by savanna ecosystem (Rutherford and Westfall, 1994). The ecosystem can be divided into arid having soils rich in nutrient and the one with soil poor in nutrient which is moist savannas (Huntley, 1982). Trees of genus Acacia dominated the nutrient-rich savannas, whereas the species from the families Corsalpinaceae and Combretaceae dominated nutrient poor sites (Scholes, 1988).

3.1.3. Climatic factors

Nylsvley receives the mean rainfall of about 630 mm and 19.0 °C is mean annual temperature (Scholes and Walker, 1993). It has a seasonal climate of wet and hot summers with 623 mm mean annual precipitation of which eighty-five percent falls between October and March (Huntley and Morris, 1982). The mean daily temperature in summer is from 16°C to 30°C and in winter from 6°C to 21°C. Frost occurs on average 20 days per annum between June and mid-August (Rutherford, 1984).

The soil is essentially sandy in the south and east, except Maroelakop and Stemmerskop where sandstones of the Waterberg system formed the soil. The loam or clay underlain the area to west and north, along flat country flanking the Nyl river (Tshisikhawe *et al*., 2012).

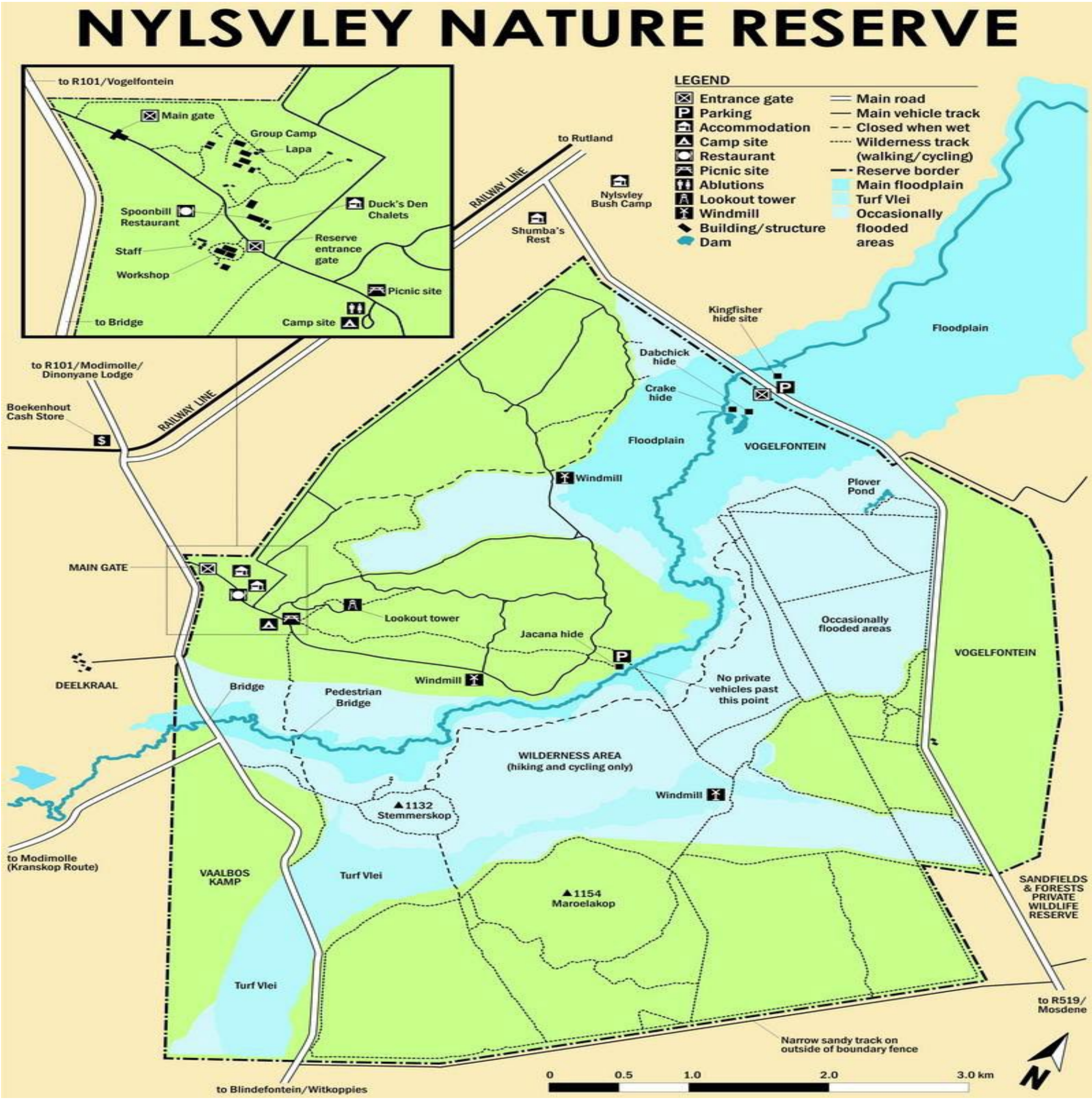

Figure 3.1: Nylsvley Nature Reserve map.

3.2. Methodology

The study site was located subjectively in an area dominated by the species under study. Sampled individuals were randomly selected making sure the same individual is not sampled more than once. This was achieved by marking the sampled individuals with danger taped iron rods. Twenty juvenile and adult trees of the two species were selected where one lateral root was cut by a saw per tree. The lateral root was located by digging with a pick. The soil was removed and after root cutting put back to cover the roots using a spade. The danger taped iron rods were placed where root was cut using a hammer. Cutting of the roots was done once in one season of the year which was late spring (November 2020).

The data was collected after three months' interval: March 2021, four months' interval in August 2021 and finally two months' interval in November 2021 and different seasons. Root suckers were expected to be produced from different site with root suckers A representing proximal root suckers produced from root connected to the plant and root suckers' B representing distal root suckers produced by root disconnected to the plant. The following parameters were averaged: tree basal stem diameter, crown, and height; and root sucker height and diameter within selected species. Number of root suckers produced were added within species. The diameter and height were arranged in range within the species.

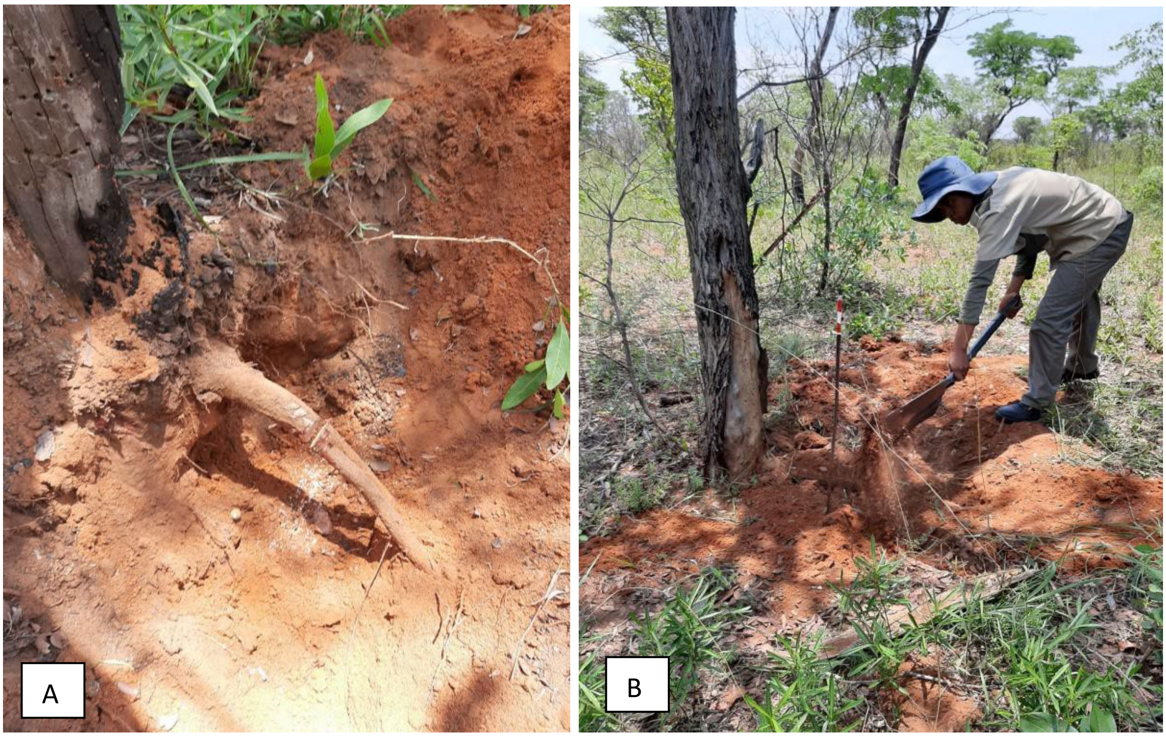

Figure 3.2: The lateral root cut by saw (A), danger taped iron rod placed and soil put back (B).

3.3 Data collection and analysis

The data collection sheet sample is shown in Appendix A. Data was analyzed using Microsoft excel. The data was collected in different seasons: Early autumn (March 2021), Late winter (August 2021) and late spring (November 2021). The parameters of data collected in each selected species are listed below:

A. Basal stem diameter (cm) of trees was measured using diameter tape (Figure 3.3). The diameter tape was only used in measuring the diameters of juveniles and adult trees.

Figure 3.3: Measuring basal stem diameter using diameter tape.

B. Tree height (m) was measured by an aggregated 8 m measuring pole. Reverted to estimation in case where trees were taller than 8m (Figure 3.4).

Figure 3.4: Measuring tree height using height meter rod.

C. Tree crown (m) was measured with an aid of an aggregated measuring tape (Figure 3.5). Measuring tape was stretched from one end of the canopy to another end. Longest canopy size was consistently used in determining the canopy diameter size.

Figure 3.5: Measuring tree crown.

D. Direction of root cutting was determined by where the danger taped iron rod was placed as in figure 3.6.

Figure 3.6: How the direction of cut was determined.

E. Number of root suckers produced were counted.

F. Root sucker heights (m) were measured using an aggregated measuring tape as in figure 3.7.

Figure 3.7: Measuring root sucker height.

G. Root sucker diameter (cm) was measured using venire caliper (Figure 3.8).

Figure 3.8: Measuring root sucker diameter.

CHAPTER 4

RESULTS

4.1 Production of root suckers

Burkea africana produces more root suckers compared to *T. sericea* in both juvenile and adult plants (Figure 4.1 and 4.2). *B. africana* juvenile plants (35, 34 and 30 in March 2021, August 2021, and November 2021 respectively) produced more distal root suckers compared to adult plants (13, 35 and 23 in March 2021, August 2021 and November 2021 respectively). *T. sericea* juvenile plants (3, 1 and 0 in March 2021, August 2021, and November 2021 respectively) produced distal root sucker even though they are few as compared to *B. africana* but more to *T. sericea* adult plants which did not produce any root sucker. Proximal root sucker was produced by *B. africana* in November only. In this study, more distal root suckers were produced compared to proximal root suckers. On few occasions, there was a connection between root connected to the plant and root disconnected to the plant.

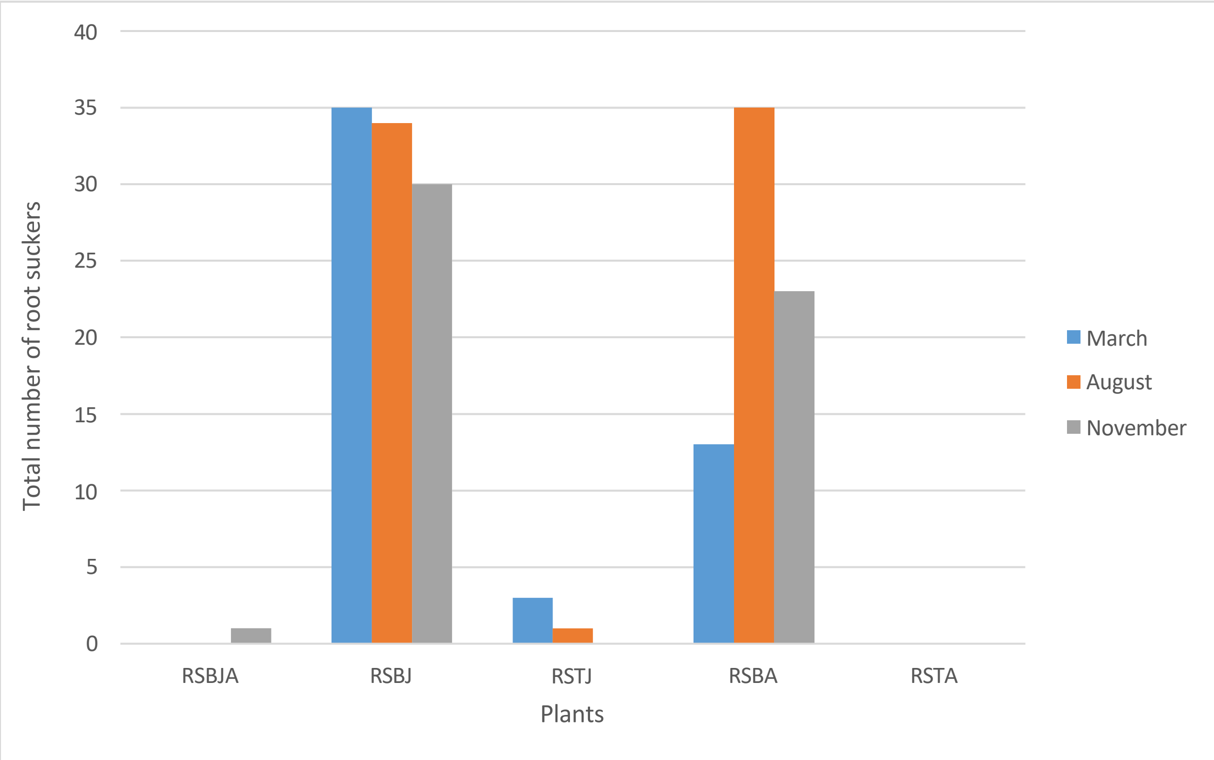

Figure 4.1: Number of root suckers produced by juvenile plants of *Burkea africana* and *Terminalia sericea*.

Figure 4.1 presents results that are represented as follows: RSBJA stand for proximal root sucker (root sucker produced by roots connected to the plant) of *Burkea africana* juvenile plants. Other root suckers were produced by roots disconnected to the plant, distal root suckers. RSBJ stand for distal root sucker produced by *B. africana* juvenile plants. RSTJ stand for distal root sucker produced by *Terminalia sericea* juveniles. RSBA stand for distal root sucker produced by *B. africana* adult plants. RSTA stand for distal root sucker produced by *T. sericea* adult plants.

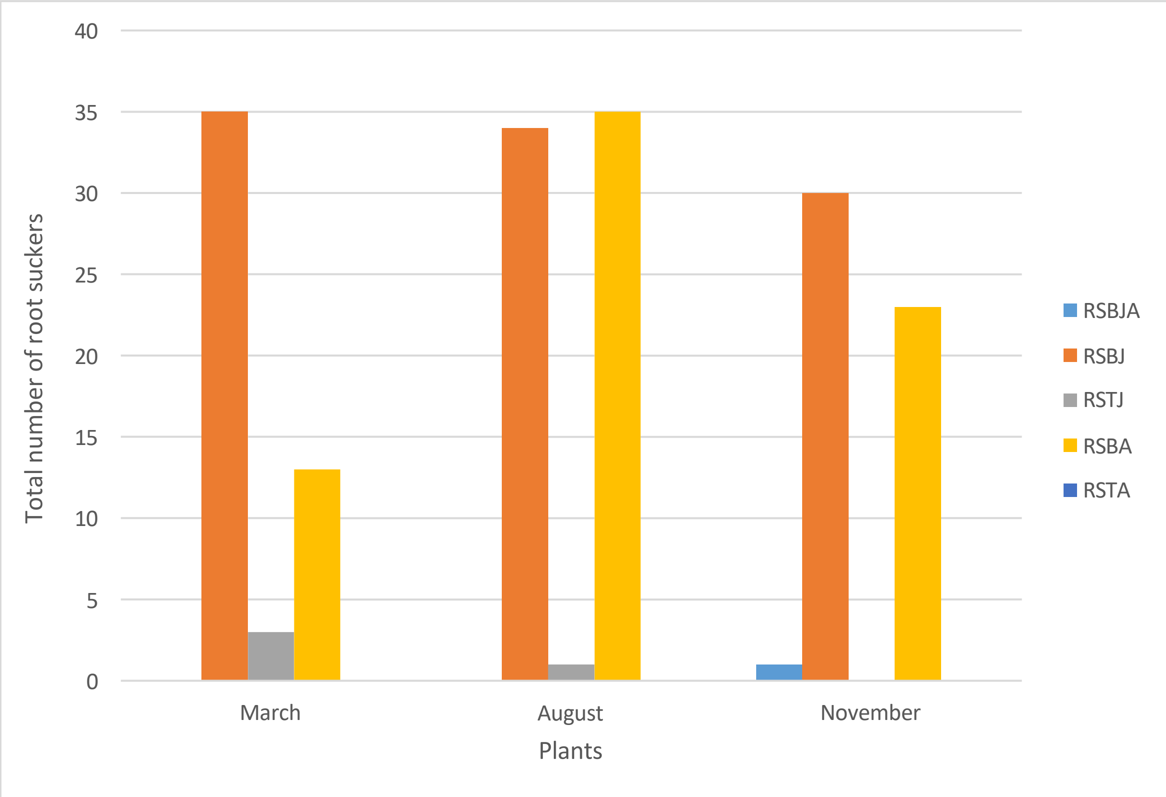

Figure 4.2: Number of root suckers produced by adult plants of *Burkea africana* and *Terminalia sericea*.

The results in Figure 4.2 are presented as follows: RSBJA stand for proximal root sucker (produced by roots connected to the plant) of *Burkea africana* juvenile plants. Other root suckers were produced by roots disconnected to the plant, distal root suckers. RSBJ stand for distal root sucker produced by *B. africana* juvenile plants. RSTJ stand for distal root sucker produced by *Terminalia sericea*. RSBA stand for root sucker produced by *B. africana* adult plants. RSTA stand for root sucker produced by *T. sericea* adult plants.

Burkea africana plants whose roots where cut in the northern direction produced more root suckers as compared to other directions except in the adult plants in August were root suckers produced were more in the southern direction of root cut (Figure 4.3).

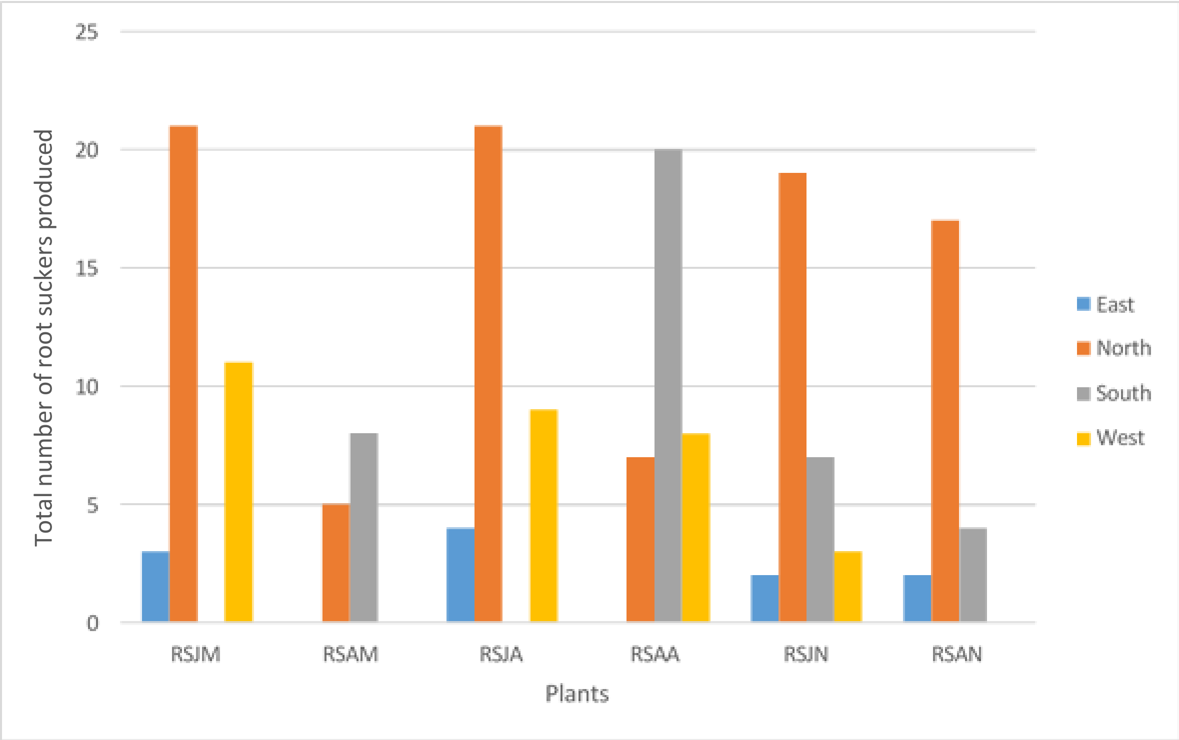

Figure 4.3: Number of root suckers produced by *Burkea africana* plants in different direction of root cut.

In figure 4.3 results are represented in the following: RSJM stand for root sucker produced by juvenile plants in March 2021. RSAM stand for root sucker produced by adult plants in March 2021. RSJA stand for root sucker produced by juvenile plants in August 2021. RSAA stand for root sucker produced by adult plants in August 2021. RSJN stand for root sucker produced by juvenile plants in November 2021. RSAN stand for root sucker produced by adult plants in November 2021.

The southern direction in *Terminalia sericea* has highest number of root suckers produced compared to western as only one plant produced root sucker (Figure 4.4.).

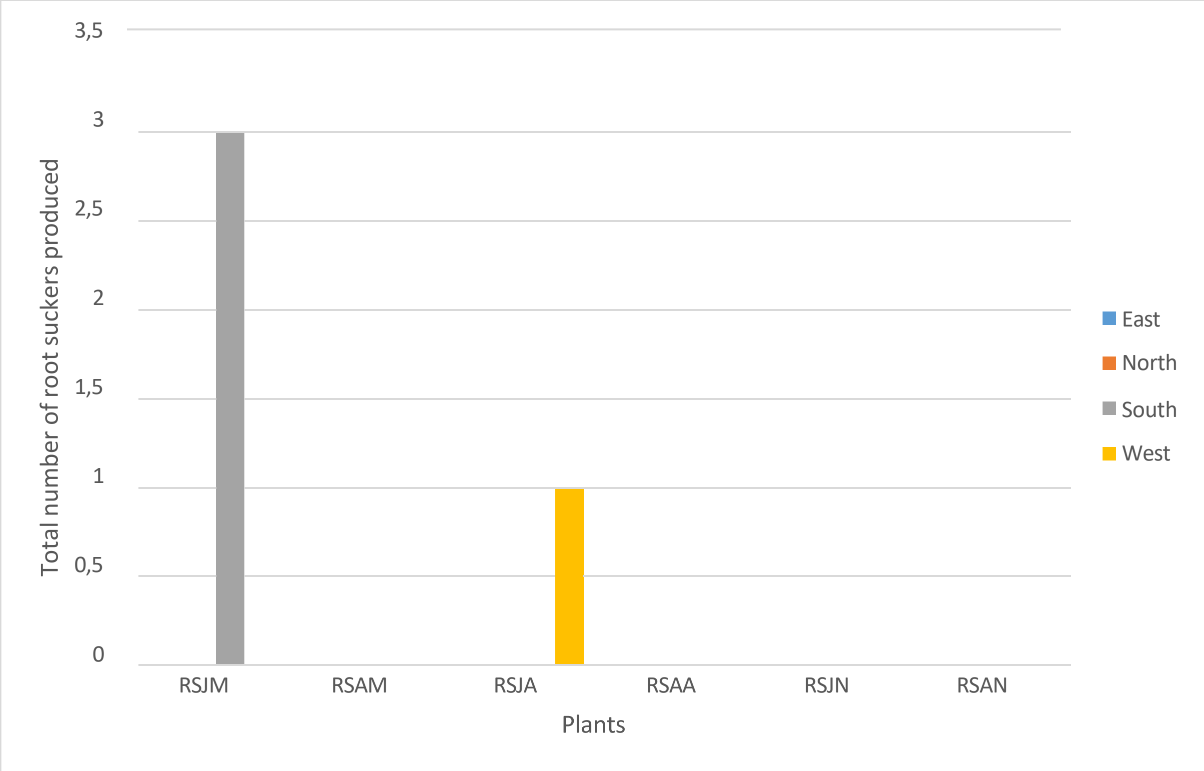

Figure 4.4: Number of root suckers produced by *T. sericea* with respect to direction of root cut.

In figure 4.4 the results are represented in the following: RSJM stand for root sucker produced by juvenile plants in March 2021. RSAM stand for root sucker produced by adult plants in March 2021. RSJA stand for root sucker produced by juvenile plants in August 2021. RSAA stand for root sucker produced by adult plants in August 2021. RSJN stand for root sucker produced by juvenile plants in November 2021. RSAN stand for root sucker produced by adult plants in November 2021.

4.2 The growth or vigor of root suckers

There was only one proximal root sucker in November (Figure 4.5). All other root suckers were distal root suckers. The root sucker's diameter of juvenile plants of *B. africana* decrease from March to November 2021 with November 2021 having the lowest whereas the root sucker height was higher in August but lowest in March. The root sucker's diameter of adult plant of *B. africana* increase from March to August but decrease a lot in November whereas the root sucker height follows the same suite but with March having the lowest.

The root sucker's diameter of *T. sericea* juvenile plants decreased from March to August and height of root suckers increased from March to August. No root suckers were produced by juvenile plants in November and adult plants in all months of *T. sericea*. The root suckers produced were browsed meaning that the height was compromised. So, in juvenile plants of *Burkea africana*, when the root sucker diameter increase, the height decreases. The adult plants of *B. africana* showed different results, when the root sucker diameter increase, the height also increases as well. *Terminalia sericea* juvenile plants respond the same as juvenile plants of *Burkea africana*.

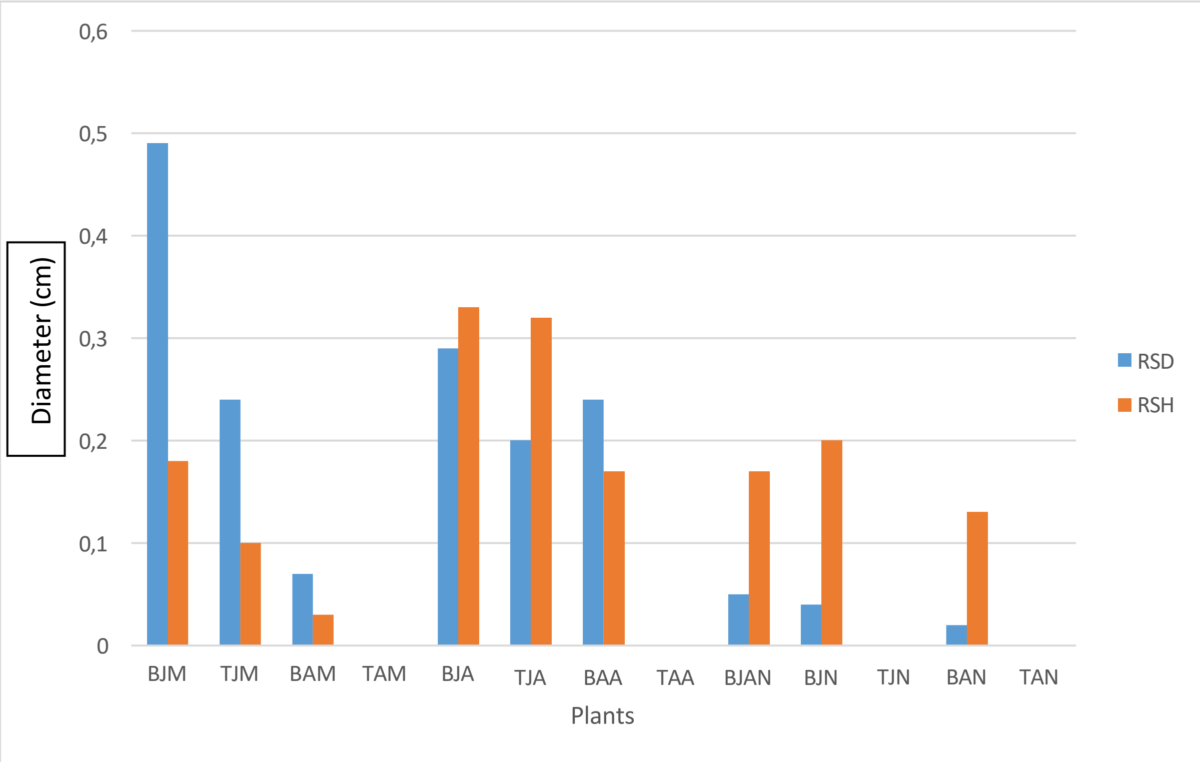

Figure 4.5: Root sucker's diameter versus root sucker's height of *Burkea africana* and *Terminalia sericea*.

In figure 4.5 the root sucker height is the average of the total height per root sucker diameter range. The results are represented in the following: B stand for *Burkea africana* while T stand for *Terminalia sericea*. Juvenile plants are represented by J and the letter A in the middle stands for adult plants. BJAN stands for proximal root sucker (produced by root connected to the plant) of *B. africana* juvenile plant in November 2021. Months are presented as M for March 2021, A for August 2021, and N for November 2021.

4.3 The health of the plant

Plants with big tree crown produced a greater number of root suckers as compared to plant with smaller tree crown (Figure4.6). *B. africana* juvenile plants have higher total number of root suckers produced but few root suckers as per plant than adult plants with lower total number of root suckers but more per plant. *T. sericea* adult plants did not produce any root sucker.

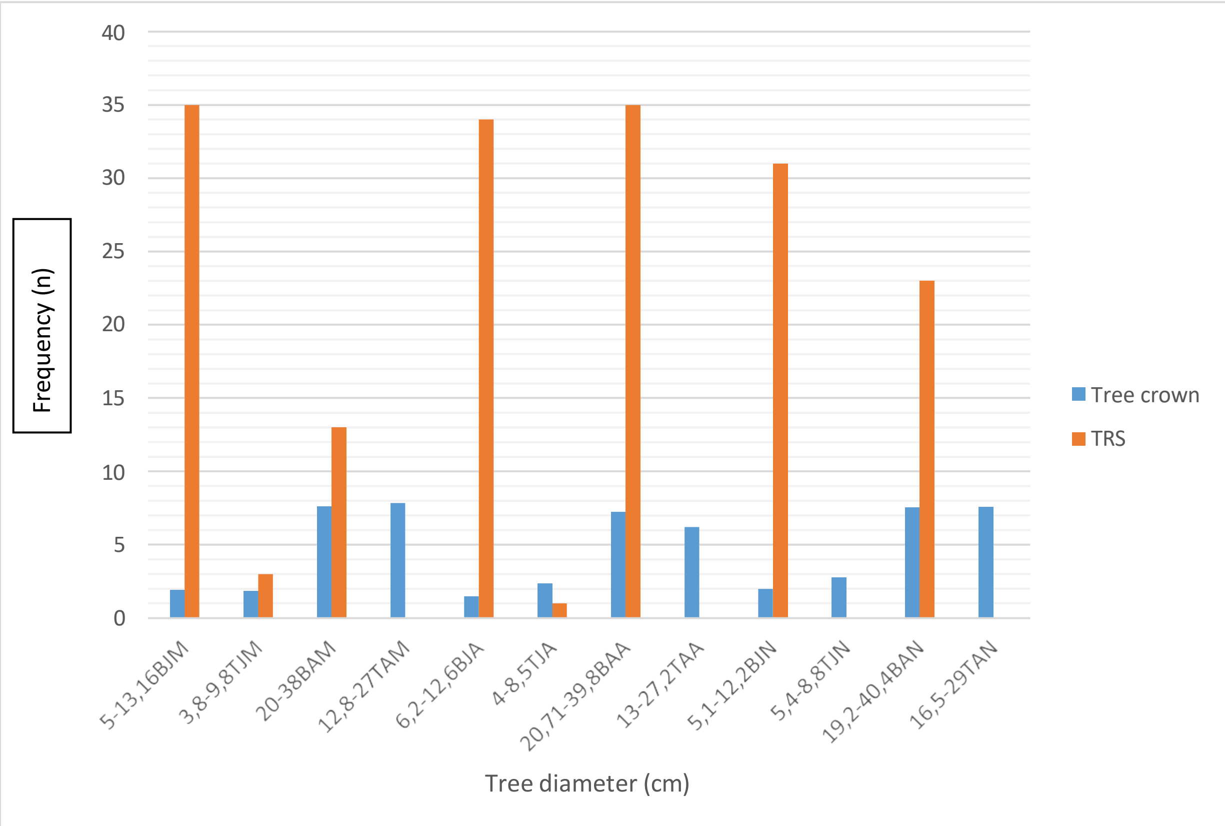

Figure 4.6: Comparison of tree crown versus number of root sucker produced by *Burkea africana* and *Terminalia sericea* plants.

In figure 4.6 tree crown is in meters representing average tree crown of the tree diameter range and total number of root sucker per tree diameter range (RS). B stand for *Burkea africana* and T for *Terminalia sericea*. J stands for juvenile plants. The letter A in the middle stands for adult plants. Months are represented by letters M for March

2021, A for August 2021 and N for November 2021.The results of *Burkea africana* are represented in the following manner: Juveniles are presented by tree diameter ranges of 5-13,16; 6,2-12,6 and 5,1- 12,2 and adults by 20-38; 20,71-39,8 and 19,2-40,4. The results of *Terminalia sericea* are represented in the following manner: Juveniles are presented by tree diameter ranges of 3,8- 9,8; 4-8,5 and 5,4- 8,8 and adults by 12,8- 27; 13-27,2 and 16,5- 29.

Plants which are higher in height produced a greater number of root suckers as compared to plant with lower tree height (Figure 4.7). *B. africana* juvenile plants have higher total number of root suckers produced but few root suckers as per plant than adult plants having lower total root suckers but more per plant. *T. sericea* adult plants did not produce any root sucker.

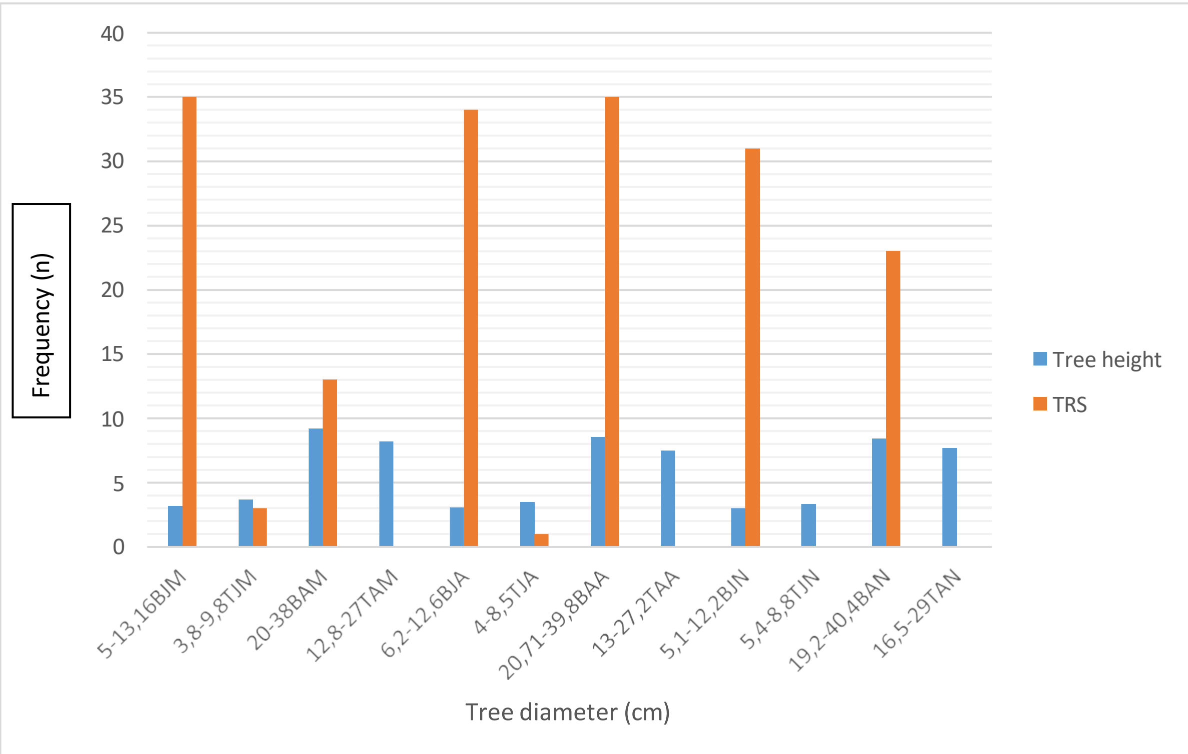

Figure 4.7: Tree height versus number of root suckers of *Burkea africana* and *Terminalia sericea*.

In figure 4.7 tree height in meters represented average tree height of the tree diameter range and total number of root sucker per tree diameter range (TRS). B stand for *Burkea africana* and T for *Terminalia sericea*. J stands for juvenile plants. The letter A in the middle stands for adult plants. Months are represented by letters M for March 2021, A for August 2021 and N for November 2021.

The results of *Burkea africana* are represented in the following manner: Juveniles are presented by tree diameter ranges of 5-13,16; 6,2-12,6 and 5,1- 12,2 and adults by 20-38; 20,71-39,8 and 19,2-40,4. The results of Terminalia sericea are represented in the following manner: Juveniles are presented by tree diameter ranges of 3,8- 9,8; 4-8,5 and 5,4- 8,8 and adults by 12,8-27; 13-27,2 and 16,5- 29.

4.4 The plant age at which root suckers are formed

Burkea africana juvenile plants distal root suckers produced by root disconnected to the plant (RSB) were decreasing from March to November 2021 (Figure 4.8), but the decrease was not that significant whereas that of adult plants were fluctuating with August having the highest number of root suckers produced (Juveniles: 35, 34 and 30 and adults: 13, 35 and 23 respectively). The juvenile plants have higher number of root suckers produced as compared to adult plants except in August where adult plants are little bit higher to juvenile plant. The juvenile plants have highest number of root suckers produced in March 2021 and lowest in November 2021 whereas adult plants have highest number in August 2021 and lowest in March 2021.

The number of adult plants which produced root suckers are less than that of juvenile plants. The adult plants which produced root suckers were only 2 in March 2021, 9 in August 2021 and 7 in November 2021 whereas juvenile plants were 20 in March 2021, 19 in August 2021 and 15 in November 2021. The difference is that adult plants had many root suckers than juvenile plants. The same pattern observed in number of root suckers produced is also observed in number of plants which produced root suckers; juvenile plants decreasing and adult plants fluctuating. Proximal root sucker from root connected to the plant (RSA) was produced by juvenile plant in November 2021 only.

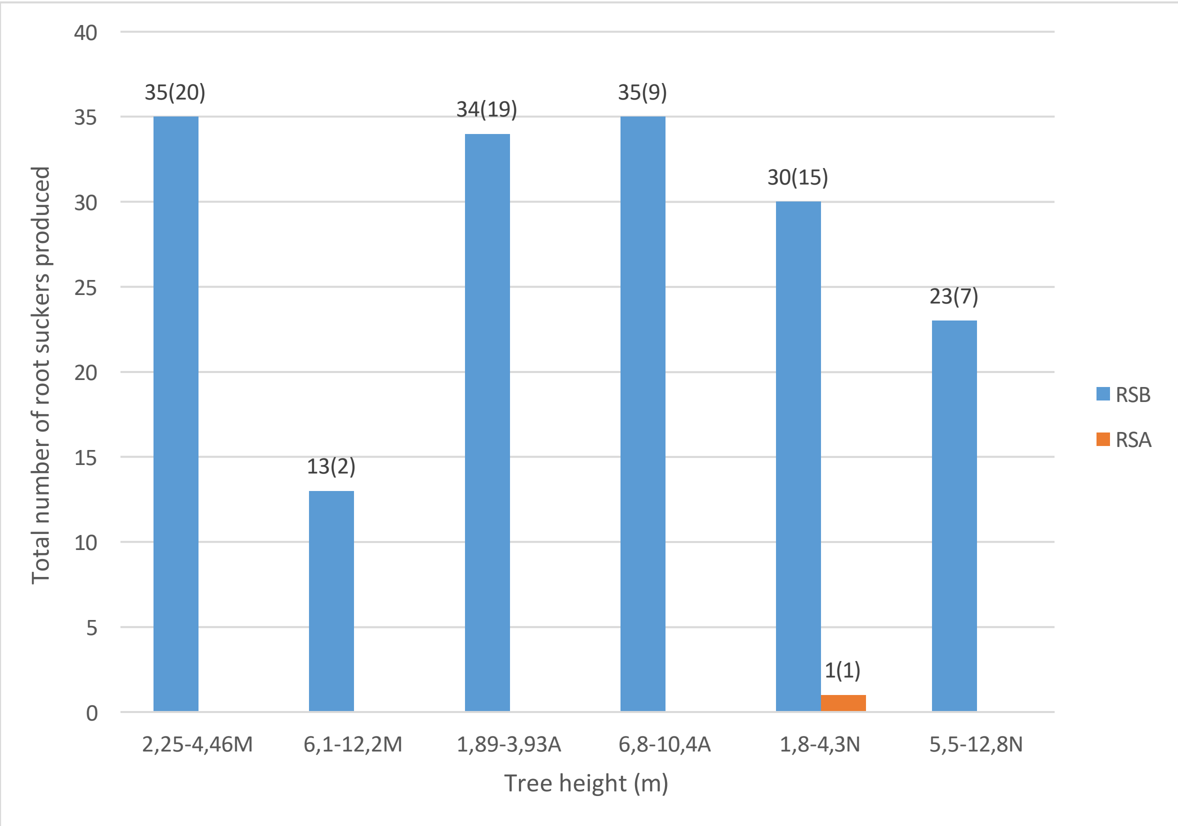

Figure 4.8: Number of root suckers produced by juvenile and adult plants of *Burkea africana*.

In figure 4.8 of *Burkea africana* results, the plant ages are represented in the following manner: Juveniles are presented by tree height ranges of 2,5-4,46; 1,89- 3,93 and 1,8-4,3 and adults by 6,1-12,2; 6,8-10,4 and 5,5- 12,8 tree height ranges. Months are represented by letters M for March 2021, A for August 2021 and N for November 2021. RSB stands for number of distal root suckers (produced by root disconnected to the plant). RSA stands for number of proximal root suckers (produced by root connected to the plant). The data labels represent total root suckers produced. The number in the brackets of data labels is number of plants which produced root suckers out of 20 selected plants.

T. sericea plants distal root suckers produced by root disconnected to the plant were in March and August 2021 only (Figure 4.9). This root suckers were produced by one juvenile in both months and adult plants produced nothing. The root suckers produced were higher in March (3) compared to August (1).

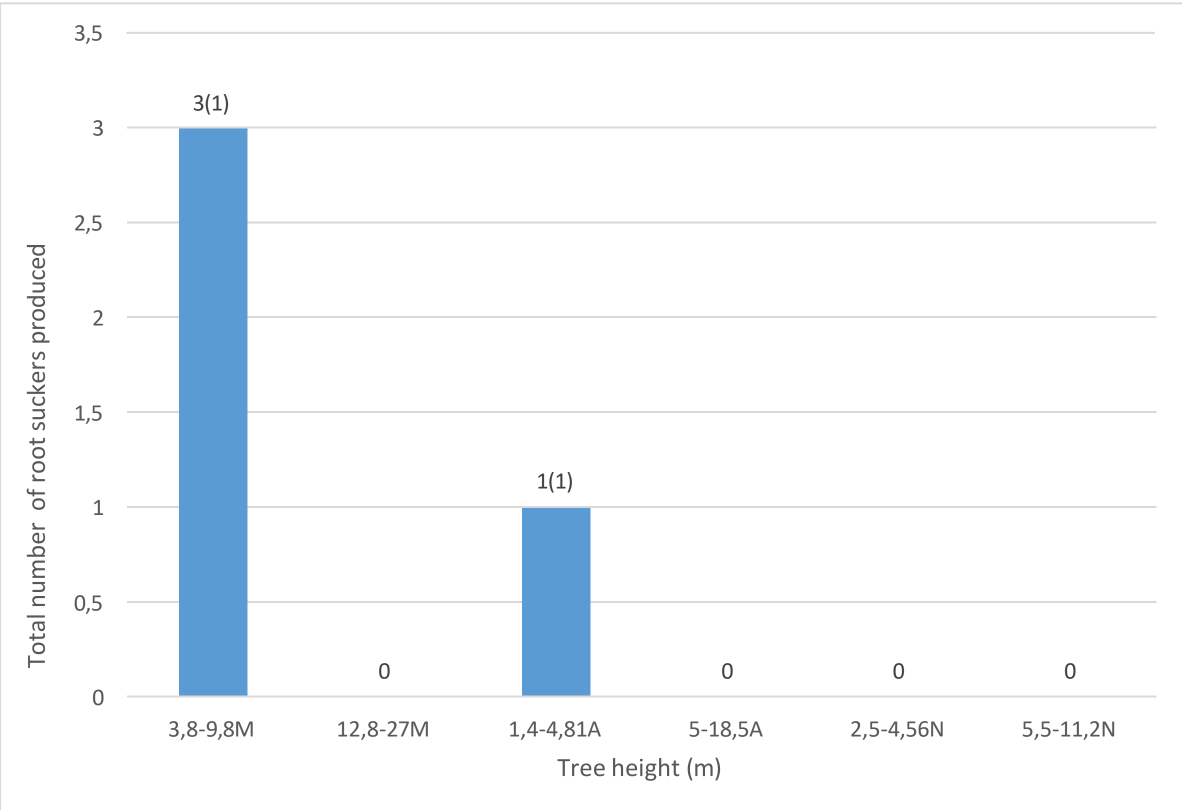

Figure 4.9: Number of root suckers produced by juvenile and adult plants of *Terminalia sericea*.

In figure 4.9 of *Terminalia sericea* results, the plant ages are represented in the following manner: Juveniles are presented by tree height ranges of 3,8- 9,98; 1,4- 4,81 and 2,5- 4,56 and adults by 12,8- 27; 5-15,4 and 5,5- 11,2. Months are represented by letters M for March 2021, A for August 2021, and N for November 2021. The data labels represent total root suckers produced. The number in the brackets of data labels is number of plants which produced root suckers out of 20 plants selected.

There is difference in root suckering of *B. africana* and *T. sericea* plants (Figure 4.10). *B. africana* produced more root suckers in both juveniles and adult plants and whereas in *T. sericea* plants only one juvenile produced root suckers. Distal root suckers produced by root disconnected to the plant were mostly produced by this species whereas proximal root sucker produced by root still attached to the plant was observed in one *B. africana* juvenile plant.

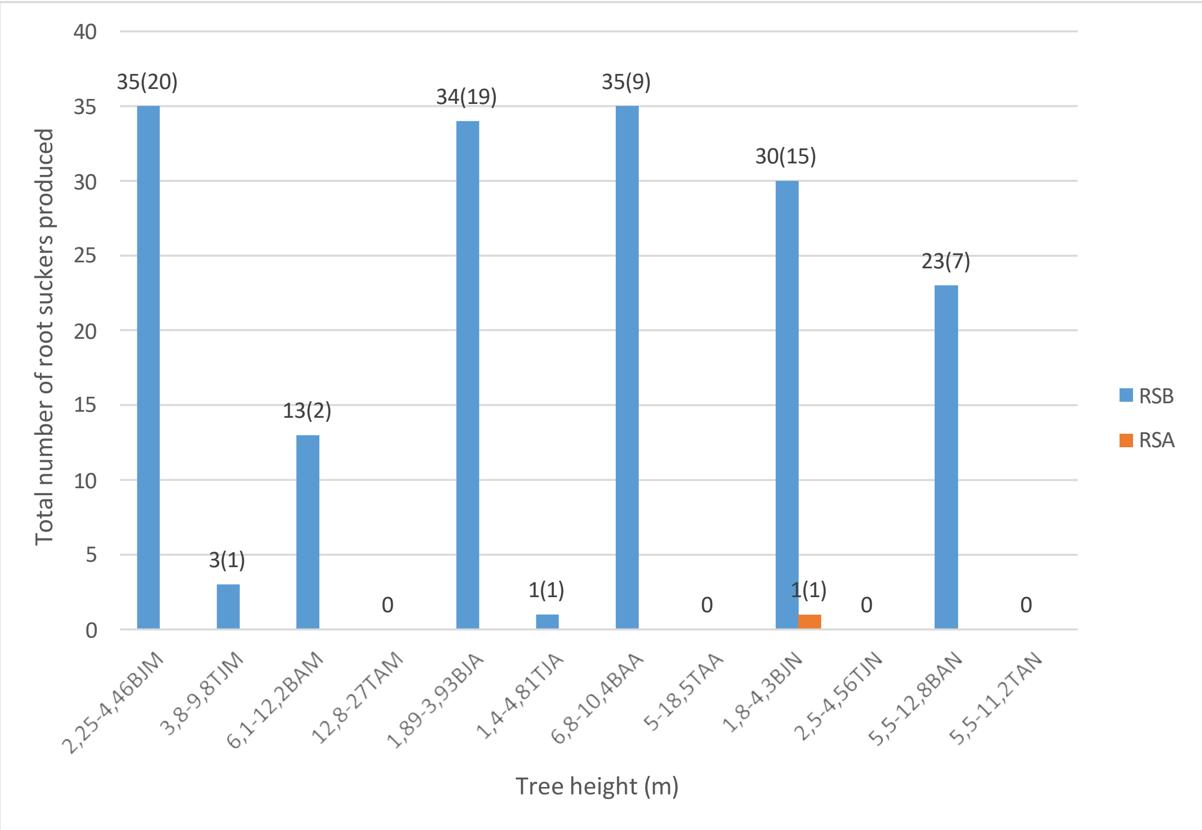

Figure 4.10: Comparison between *Burkea africana* and *Terminalia sericea*.

In figure 4.10, RSB stands for distal root suckers (produced by root no longer connected to the plant). RSA stands for proximal root sucker (produced by root still connected to the plant). *Burkea africana* plant ages are represented in the following manner: Juveniles are presented by tree height ranges of 2,5-4,46; 1,89- 3,93 and 1,8-4,3 and adults by 6,1-12,2; 6,8-10,4 and 5,5- 12,8. The results of *Terminalia sericea* plant ages are represented in the following manner: Juveniles are presented by tree height ranges of 3,8- 9,98; 1,4- 4,81 and 2,5- 4,56 and adults by 12,8- 27; 5-15,4 and 5,5- 11,2. B stand for *Burkea africana* and T for *Terminalia sericea*. Months are represented by letters M for March 2021, A for August 2021 and N for November 2021. The data labels represent total root suckers produced. The number in the brackets (data labels) is number of plants which produced root suckers out of 20 plants selected.

CHAPTER 5

DISCUSSION

5.1. Production of root suckers

There is variation and within species of aptitude to root suckering. The suckering aptitude could vary considerably because of ecological conditions (factors, season, pedoclimatic, etc.) and variability in genes (Bellefontaine, 2005; Meunier *et al*., 2008; Fawa *et al*., 2014). There is difference in the ability of root suckering between *Burkea africana* and *Terminalia sericea* and between juvenile and adult plants of *B. africana*. *Burkea africana* responded quickly but *Terminalia sericea* needs more time to develop root suckers. Temperature is important in determining early sucker development (Frey *et al*., 2003). The earlier initiation of suckers is stimulated by higher soil temperatures through the soil surface (Zasada and Schier, 1973; Maini and Horton, 1966; Fraser *et al*., 2002). The suckers that emerge earlier through soil surface was promoted by high temperatures (Zasada and Schier, 1973).

The roots physiological condition contributing to seasonal differences in the ability of suckering (Bates *et al*., 1993), such as increased auxin production (Eliasson, 1971) or low carbohydrates reserves (Bell *et al*., 1999) are thought to take place after the flushing of bud as suggested by other studies (Mulak *et al*., 2006). The time of root severance also determine how the plant will respond. This difference may be due to season when severance of root was done during cutting in late spring, November 2021.

Bell *et al*. (1997, 1999) and Farmer (1978) speculated that the sucker development success in autumn and winter is high when root carbohydrates are highest. Landhäusser and Lieffers (2003) found that in the winter and early spring root carbohydrates reserves are the lowest and this was due to pulse of growth of root in the late autumn which resulted in depleted root carbohydrates reserves by winter (Mulak *et al*., 2006). Some studies noted that suckering is higher following mid to late summer (Bates *et al*., 1993; Bella, 1986). Best sucker growth and abundant suckering are promoted when cutting is done in winter than spring or summer as noted by other studies (Stoeckler and Macon, 1956; Peterson and Peterson, 1992). As a results, roots having important amount of carbohydrate reserves favour suckers' development which is good (Landhäusser and Lieffers, 2002). It is what was found in the juvenile plants where most plants produced root suckers.

Most of the root suckers developed from root disconnected to the plant i.e, distal root suckers. This is like what Fawa *et al*, (2014) found in *Lophira lanceolate* Van Tiegh.ex Keay (Ochnaceae) which produced 100% of distal root suckers in root completely sectioned, 83.33% in roots slightly injured and only 16.67% of proximal root suckers but its natural suckering rate is low (17.83%). Noubissie-Tchiagam *et al*. (2011) reported high value of natural suckering in *Diospyros mospiliformis* (36%), *Sclerocarya birrea* (49%). *Esenbeckia febrifuga* that originated several root suckers when lateral roots were sectioned with 89 distal root suckers and 30 proximal suckers (Hayashi and Appezzato-da-Gloria, 2009). This implies that it can develop both proximal and distal root suckers with more distal root suckers. This might be the same in *Burkea africana* in this study.

The direction of root cut has negative and positive effect as well. The root cut done in the northern direction in both juvenile and adult plants of *B. africana* produced the highest number of root suckers. *T. sericea* juvenile produced higher root suckers in the southern direction as compared to one on the western direction. This may suggest that the direction of severing the root depend on the plant species.

5.2 The growth or vigor of root suckers

The growth or vigour of root suckers differ in different plant age. Juvenile plants root suckers grow differently to adult plants root suckers of *Burkea africana*. In the juvenile plants when the root sucker diameter increase, the height decreases. In adult plants, when the root sucker diameter increase, the height also increases as well. *Terminalia sericea* juvenile plants respond the same as juvenile plants of *Burkea africana*. This was also supported by what Schier and Campbell (1980) found that growth and vigour of root suckers are not limited by age as older plants had capability of producing vigorous growing suckers.

The growth of sucker is strongly correlated to roots total non-structural carbohydrates (Schier and Zasada, 1973; Landhäusser and Lieffers, 2002). Larger roots store large amount of carbohydrates. The suckers relied upon root carbohydrate reserves for the renewal of new leaf, stem and root tissue and maintenance (respiration) of root tissue surviving until they are independent, able to produce sufficient energy (Lambers *et al*., 2002). The small root segments have more restricted sucker growth due to limited total non-structural carbohydrates reserves available (Steneker and Walters, 1971).

This means that root carbohydrates reserve in the parent root system supply the sucker with energy while its photosynthetic rates are still low. Once the root suckers are above ground, the growth of emerging root suckers is promoted by factors such as high light and soil nutrients status, warm soil temperature and moderate levels of moisture (Landhäusser *et al*., 2005). On few occasions, there was a connection between root connected to the plant and root disconnected to the plant. This may explain why distal root suckers were growing vigorously.

The growth of root suckers is also determined by where they initiated. Most suckers are initiated from meristems which is newly initiated and pre-existing primordia after disturbance than from suppressed buds or short shoots. The growth of suckering arising from the other two sources tend to be more vigorous than that of suppressed buds (Schier, 1973a).

5.3 The health of the plant

The results showed that the health of the plant is not affected by the development of root suckers. Instead, the healthier plants, i.e., plants with higher tree crown and height produced higher number of root suckers as observed in *Burkea africana* plants. Tew (1970) found that higher numbers of suckers were produced by more vigorous aspen roots clones. This suggests that it might be due to either an effect of genetic susceptibility or nutrient availability to higher number of suckers on better (more competitive) sites (Frey *et al*., 2003). However, it is contrary to what Hoffman *et al*. (1999) found that the number and growth of suckers was reduced by the canopy shade.

Other researchers found that vitality (Watson, 1998) and growth (Pretzsch *et al*., 2016) as well as altered physiological processes (Benson *et al*., 2019a) can be reduced by removing roots. However, vigour can be kept if roots concentration near tree base is present although pruning of root may be very close to tree trunk (Hamilton, 1989). Hamilton (1988) said that if the reserves of carbohydrates are in great amount the performance and recovery chances of severed roots is increased.

Other studies have found that in aspen canopy which is partial leads to lower recovery densities (Bates *et al*., 1993; Stoeckler and Macon, 1956; Crouch, 1983; Schier and Smith, 1979; Hoffman *et al*., 1999; Bella, 1986). This implies the effect which tree canopy has on the recovery of the plant when the remaining part of trees after disturbances might be keeping higher auxin: cytokinin ratios which limit suckering of root (Eliasson, 1971; Frey *et al*., 2003). The development of suckers is limited by the auxins produced in the above ground part of the clone. This is because a very large network of connected roots transport auxin (DesRochers and Lieffers, 2001). So, the effect of roots severance and development of root suckers differ from species to species.

The role played by tree height in relation to production of root suckers is not yet studied directly. The assumption may be made that taller trees would produce more stump sprouts and root suckers because of having very large root system. King and Landhäusser (2018) found that aspen tree with large diameter (DBH = 6.4 cm) produced more root suckers than trees with small diameter (DBH = 4.4 cm) due to their significantly larger root systems. This concurs with our study regarding *Burkea africana*.

However, it was different in *Terminalia sericea* plants with lower tree crown and height produced more root suckers and those with higher tree crown and height.

5.4 The plant age at which root suckers are formed

When comparing the juvenile plants to adult plants, juvenile plants produced more root suckers in both *Burkea africana* and *Terminalia sericea*. The adult plants were mostly disturbed by fire as they were growing in savanna ecosystem. This might be the reason why they could not produce more root suckers as more energy is put on recovery.

These results are similar to what Maini (1968), and Peterson and Peterson (1992) found in aspen where fewer suckers were often produced by older trees (≥80 years). It is due to the decay in their root systems; although high amount of root decay has also been found on some young stands (DesRochers and Lieffers, 2001). However, Horton and Maini (1964) observed root suckers produced by a slashed 5-year-old clonal aspen stand and King and Landhäusser (2018) found root suckering that were planted in 8 and 12 years old aspen seedlings.

Watson (1998) suggested that the juvenile trees have higher tolerance of root removal than adult. This may be due to allocation of resource changes in trees reaching maturity (Pryor and Watson, 2016). Root segments which are larger store higher quantities of carbohydrates, which turn to limit suckering (Waschowski *et al*., 2014). Root suckers depend on reserves stored by the roots until they are independent (Lambers *et al*., 2002). Smiley (2008) suggested that the smaller trees may be less prone to lateral root cutting compared to trees which are larger.

CHAPTER 6

SUMMARY, CONCLUSION, RECOMMENDATION AND REFERENCES

6.1 SUMMARY

Root severance has effect on *Terminalia sericea* and *Burkea africana*. *B. africana* is a deciduous tree belonging to the family Fabaceae (Caesalpinioideae). *Terminalia sericea* is a deciduous tree belonging to the family Combretaceae. Trees respond to root severance in different ways including producing root suckers.

Root suckering take place usually following disturbance events such as fire, root severance. The root suckers originate from primordia which are formed from meristematic cells in the cork cambium of the roots during secondary growth. The suckering of roots allows individuals spreading from the original establishment site, thereby promoting new sites colonization. Root suckering is affected by light, soil temperature, soil aeration, growth regulators, hormones, and root carbohydrates reserve.

Study site was located subjectively in an area dominated by the species under study. Twenty juvenile and adult trees of the two species were selected where one lateral root was cut. The data collected in each selected species are tree basal stem diameter, tree crown, and tree height; direction of root cut; number of root suckers produced; root sucker diameter and height. The suckering of roots allows individuals spreading from the original establishment site, thereby promoting new sites colonization.

The result shows that root severance by producing root suckers as observed in *Burkea africana* and *Terminalia sericea*. More distal root suckers were produced than proximal root suckers. The health of the plant is not affected by either severing root or development of root suckers. The growth or vigour of root suckers depends on the parent root system, where they are initiated, micro environmental conditions. Juvenile plants produced more root suckers with few plants compared to adult plants of *Burkea africana*. *Burkea africana* responded quickly but *Terminalia sericea* required more time to develop root suckers.

6.2 CONCLUSION

The result shows that root severance has effect on *Terminalia sericea* and *Burkea africana*. Trees respond to root severance by producing root suckers as observed in *Burkea africana* and *Terminalia sericea*. More distal root suckers were produced than proximal root suckers. The direction of root cut is also an important factor that need to be considered when severing roots. In juvenile plants of *Burkea africana*, root suckers were mostly produced in the northern direction. The health of the plant is not affected by either severing root or development of root suckers. The growth or vigor of root suckers were affected by the browsers as they were mostly browsed. The growth or vigour of root suckers depends on the parent root system, where they are initiated, micro environmental conditions such as soil temperature and herbivory.

The plant age is more important in the production of root suckers. Juvenile plants produced more root suckers compared to adult plants of *Burkea africana*. *Terminalia sericea* responded differently to *Burkea africana*. *Burkea africana* responded quickly but *Terminalia sericea* needs more time to develop root suckers. It can be concluded that severing root induce the production of root suckers. Root suckering allows individuals spreading from the establishment site which promotes the colonization of new sites as it promotes vegetative propagation. This can be another way of increasing the population of *Burkea africana* and *Terminalia sericea* in the savanna ecosystem.

6.3 RECOMMENDATIONS

In research of this nature, the following may be considered:

- The method used might be 2 or 3 as to know the difference. For example, in study done by Fawa *et al*. (2014), the roots after cutting were covered and others exposed. The results were different. Only one method of covering roots was done, cutting was done in one season and cutting only one lateral root per plant.
- Marking of the selected trees must be done in a way as to be systematic when collecting data for several times. In this research selected plants were just marked by the danger taped rod but without numbers or symbols which would make data to be systematic.
- The distance of cutting of lateral root from the tree trunk need to be taken into consideration.
- The depth of the lateral root to be cut in the soil should also be considered during cutting.
- This research needed more time as results were observed in one year only. There are still unanswered questions of what would happen after two or more years.

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APPENDIX A

Data sheet form

Species:

Growth stage:

Tree no.	Tree Diameter (cm)	Tree Height (m)	Tree crown (m)	Direction of root cutting	Root suckers A										Root suckers B									
1.					No	H									No	H								
						D										D								
2.					No	H									No	H								
						D										D								
3.					No	H									No	H								
						D										D								
4.					No	H									No	H								
						D										D								
5.					No	H									No	H								
						D										D								
6.					No	H									No	H								
						D										D								
7.					No	H									No	H								
						D										D								

No: Number of root suckers produced H: Root sucker height (m) D: Root sucker diameter (cm)