Title: The phenological study of *Securidaca longepedunculata,*

in the Nylsvley Nature Reserve,

Limpopo Province,

South Africa

By

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Dissertation

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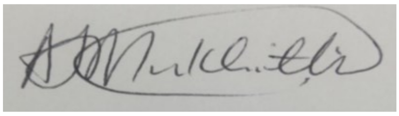
DECLARATION

I, Aluwani Godfrey Mukhithi, declare that this research is my original work and has not been submitted for any degree at any other university or institution. The research does not contain other persons' writing unless specifically acknowledged and referenced accordingly.



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Signed (Student): .... Date: ....

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ABSTRACT

Phenological observations were conducted through analysis of phenological phases and stages of 200 sampled *S. longepedunculata* plant individuals in the sandy soil areas of Nylsvley Nature Reserve, Limpopo Province, South Africa. Phenological stages comprised of onset, peak development and decline; while phenological phase is time spent by those stages for example leaf yellowing (Ruml and Vulic, 2005). Phenological phases patterns were analysed by focussing on vegetative and reproductive phenophases. Vegetative phenophase considered the presence of budding and developmental stages of leaves until they are shed. Reproductive phenophase considered the presence of flowering and developmental stages of fruits until they are shed. Phenological data was mainly collected through direct ground based observation. The results showed that budding, leaf greening and flowering were observed from mid spring in September in response to upcoming summer which is warmer and rainy. Ripe seeds and leaf yellowing were predominantly visible in autumn and winter respectively, as they are in their annual maturity stage. Leaf and seed shedding were observed at their peak development from late winter in June to early spring in August, probably due to the effect of windy conditions on site. Changes in the phenology of *S. longepedunculata* plant individuals caused by environmental changes resulted in changes at the community level. This shows that thorough phenological pattern monitoring is essential in order to forecast plant species behaviour. Also, it is necessary to provide knowledge on proper management of the reserve and protection of the plant species.

Key words: *Securidaca longepedunculata*, phenological phase, phenological stages, phenology, vegetative phenophase, reproductive phenophase

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CHAPTER 1: INTRODUCTION

1.1. Background to the study

This research's phenological study shows how to observe the life cycle of *S.longepedunculata* plant individuals throughout the year by looking at their phenological phases and stages. The rarity of *S.longepedunculata* plant individuals and the necessity for conservation are linked through the study of these phenological phases and stages. The distribution and uses of *S.longepedunculata* plant individuals across Africa are also highlighted in the study's background.

1.1.1 Linking phenological study with conservation.

The study of changes in the timing of plant life cycle events is critical to our knowledge of rarity and the conservation of rare plant taxa (Drury, 1974; Ayensu, 1981; Kruckeberg and Rabinowitz, 1985). Phenological investigations have proven to be effective in the development of various habitat-specific programs. Research on reproductive phenology (Sakai et al., 1999) has aided in the development of conservation strategies for rare species and is essential for restoration and reintroduction. The design of successful *in situ* conservation management programs for any plant population, particularly endangered plant populations, is heavily influenced by reproductive phenology (Kallarackal and Renuka, 2015).

1.1.2. Distribution of *Securidaca longepedunculata*

Although *S. longepedunculata* grows (in areas dominated by acidic soil with texture ranging from sandy to rocky) in different climates and altitudes (Ndou, 2006), it is well distributed in tropical Africa ranging from Senegal (Burkill, 1985), Ethiopia (Gidey *et al*., 2015) and Namibia (Hedimbi and Chinsembu, 2012). Of the nine provinces of South Africa, the species is predominantly found in two provinces, namely North West and Limpopo (Van Wyk and Van Wyk, 1998). Individual *S. longepedunculata* plants develop in confined and selective habitat circumstances, as evidenced by the above mentioned distributions.

1.1.3. Uses of *Securidaca longepedunculata* in various African countries

Securidaca longepedunculata is used in various ways across different countries. Nengonengo, the native name for *S. longepedunculata*, is without a doubt the most sought-after medicinal tree in Tanzania's Shinyanga region. It is at the top of practically every district's and user group's priority lists. The powdered root is a powerful purgative in tiny doses, and it's a popular treatment for children's convulsions (Dery , 1999). Roots that have been crushed and powdered are used as an intravaginal or intrarectal poison in Zambia (Gilges, 1955).

Senegal uses the bark as a crude medicine because of its anti-inflammatory and antibacterial effects. Antibacterial and antifungal properties were found in leaf and root bark extracts. Ndamitso *et al*., 2013; Karou *et al*., 2012; Musa *et al.*, 2013). A 70 percent methanol extract of the leaf was recently found to have a MIC of 1.2 mg/ml against *Mucor rouxi*, *Fusarium oxysporum,* and *Rhizopus nigricans* (Karou *et al*., 2012). In Zimbabwe, the roots are used to heal persons who appear to be possessed by evil spirits, and it's also used to treat snake bites (Ndou, 2006).

In Nigeria based on twenty reports on the different organs of *S. longepedunculata* usage as medical plant, it revealed that nine reports that constitute 47.6% of the data collected were used as root, six reports about 28.6% were used as bark while five reports prescribed the use of leaves at about 23.8% (Mustapha, 2013). Indigenous knowledge of *S. longepedunculata*'s therapeutic uses is dynamic, changing with healers and disease conditions (Mustapha, 2013). The methanol root extract of *S. longepedunculata* possesses excellent trypanocidal properties and some degree of antitrypanosomal effect thereby giving some level of credence to its traditional use in northern part of Nigeria for the treatment of sleeping sickness (Gabriel *et al*., 2015).

In Ghana, it is traditionally used to control insect pests of stored grain and legumes. (Belmain *et al*., 2001). The root powder of *S. longepedunculata*, its methanol extract, and the major volatile component, methyl salicylate, are repellent and harmful to adults of *Sitophilus zeamais,* and are widely employed as pesticides (Jayasekara *et al*., 2005). Small-scale farmers in Africa utilize the powder as a required alternative pesticide because they may lack the resources or funds to purchase synthetic pesticides (Stevenson *et al*., 2014). Pesticidal plants have long been an important part of African farmers' traditional pest management practices (Stevenson *et al.,* 2014).

The xanthones in *S. longepedunculata* relax the corpus cavenosum smooth muscle, which supports the traditional use of the root bark in the treatment of erectile dysfunction in South Africa (Meyer *et al*., 2008). There are findings that support anecdotal, folkloric, and ethno-medical uses of *S. longepedunculata* root-bark in the treatment, management, and/or control of painful, arthritic, inflammatory conditions, as well as in the management and/or control of type 2 diabetes mellitus in some rural communities of South Africa (Ojewole, 2008).

The roots are used by the *Vhaveṋḓa* people of the Vhembe District to prevent mental diseases, with the notion that the cure may help protect children from illnesses while breastfeeding (Ndou, 2006). The powdered roots are used as an aphrodisiac by many Africans to increase male sexual vigor. The *Vhaveṋḓa* people blend the powdered root with a traditional drink called *'mageu,'* which is produced from maize or sorghum and offered to a man who is sexually weak (Ndou,2006).

Considering its massive medicinal uses, this research focused on identified two hundred *S. longepedunculata.* Selected phenological phases and stages of S. *longepedunculata* were observed and analysed.

1.2. Problem Statement

Phenological studies on medicinal plants (e.g *S. longepedunculata*) are lacking in South Africa. Almost all medicinal plants are still found in the wild, with little effort put into domestication or *ex-situ* conservation. There has been an increased focus in recent years to monitor plant phenology in different biomes (Gray and Ewers, 2021) as it is strongly linked to aspects of ecosystem processes and biodiversity.

Securidaca longepedunculata is an indigenous medicinal plant in Africa. It occupies a significant position in both traditional and contemporary medicine. *Securidaca longepedunculata* stem bark and roots are still among the most traded medicinal plants in Africa, despite being protected by provincial and national legislation (Moeng, 2010; Tabuti *et al*., 2012). Various anthropogenic and environmental factors, such as seasonal fires, droughts, and debarking, pose a threat to the species (Oni *et al*., 2014). The fact that the roots are targeted makes it impossible for the plant to endure frequent harvesting for medical purposes, which puts it in threat.

Securidaca longepedunculata is a red listed South African plant on the National Forest Act of 1998 of South Africa and is regarded as the least concerned plant. Traditional healers in the Vhembe District of South Africa's Limpopo Province employ medicinal herbs to treat diabetes. In South Africa *S. longepedunculata* was amongst the top mentioned medicinal plants used for treating diabetes by traditional healers in Vhembe District (Mudau *et al*., 2021).

1.3. Rationale of the study.

The ethnobotanical and ethnopharmacological research of multiple medicinal plants is particularly important in the formulation of any sustainable management program for genetic resource conservation and usage of these various medicinal plants (Oni *et al*., 2014).

Traditional herbal plants are getting significant attention in global health debates (Tilburt, 2008). Several authors have reported on the use of *S. longepedunculata* as source of different active ingredients used for different ailments (Adeyemi *et al*., 2010; Galeffi *et al*., 1990; Meyer *et al*., 2008; Ojewole, 2008). *Securidaca longepedunculata* is a significant plant species with potential therapeutic benefits in the treatment of transmissible and infectious diseases such as malaria, tuberculosis, and infections caused by acquired bacteria (Mongalo *et al*., 2015).

Information on phenology of *S. longepedunculata* can also be of great assistance in helping scientists to understand its vegetative and reproductive stages. Data collected can be of great importance to conservation authorities responsible for determining future conservation status of the plant as it faces prolonged demand of plant parts used as source of medicine (Ndou, 2006). The prioritised phenological phases and stages of *S. longepedunculata* will be used to determine suitable phenophases for further studies e.g. seed collection period for seed banks.

The changes or shift in the timing of phenological events can also be used as an indicator of changing climates**.** As a result, understanding the timing and variability of phenological events provides valuable information for planning, organizing, and timely implementation of certain standard and special preventive and conservative measures that require advanced knowledge of the dates of specific phenophase stages of *S. longepedunculata* development. With this field survey conservation program can be created to predict conservative measures in our rural communities aiming to safeguard the overexploitation of *S. longepedunculata* population.

1.4. Aim of the Study

The study aims to research on the phenology of *Securidaca longepedunculata*.

1.5. Objectives of the Study

The following objectives were investigated:

- to determine the onset time of the different phenophase.
- to identify the peak development and decline stages of the each phenophase.
- to determine the duration of each selected phenological phase.
- to examine the relationship between each phenophase and the seasonal climatic conditions.

1.6. Hypothesis

Understanding the reproductive phases of *S. longepedunculata* is key to keep its survival while studying the different phenophases will fully equip biologists with knowledge on management and conservation of *S. longepedunculata* that is used as source of medicinal extracts especially by *Vhavenḓa* cultural group.

1.7. Limitation of study

The study was limited to Nylsvley Nature Reserve, Limpopo Province, South Africa. Observation was more qualitative than quantitative. Observation were limited to monthly recordings. Phenological phases and stages were observed and recorded on the two hundred sampled and selected plant individuals. The vegetative and reproductive phenophases were observed as phenological variables. Vegetative phenological phase was sub divided into budding, leaf greening, leaf yellowing and leaf dissemination, while reproductive phenological phase was sub divided into flowering, unripe fruits, ripe fruits and seeds dissemination. The sharing of 100% within the phenological phases and stages of individual plants between dormant phase in August 2019 and sprouting phase in September 2018.

CHAPTER 2: LITERATURE REVIEW

2.1. Concept of Phenology

Phenology is defined as the study of plant and animal life cycle phases in relation to their temporal occurrence throughout the year (Leith, 1973). The research allowed for a phenological calendar, in which the seasons of the year were denoted by timed sets of phenological events rather than calendar dates. The events had a lot more relevance when it comes to describing and understanding seasonal ecological processes (Collinson and Sparks, 2008). Scientists studying in the temperate zones of the globe have adapted phenological events of higher plants to seasonal changes in the physical environment in one way or another. More than 400 phases of flora, fauna, and the physical environment were monitored at eight European sites where phenological calendars were used to define the start, length, and mutual interactions of seasonal natural occurrences. They were used to define the seasonality of environmental conditions, ecosystems, and individual species. Among other types of seasonal data, calendars featured phenological phases of live species, seasonal phases of environmental variables, and instrumentally measured climatic parameters (Ahas and Aasa, 2003). Phenological calendars were a way for analyzing seasonal phenomena and graphically depicting seasonality. Phenological phases were a useful technique to climate change studies because they demonstrated variations in climate and natural processes in an integrated way. At the same time, climate change had a significant impact on creatures and ecosystems (Peñuelas and Filella, 2001).

In temperate deciduous forests, phenological phenomena like bud burst were strongly linked to ecological processes (Van Vliet *et al*., 2003). Phenology thus seeks to observe easily discernible growth phenomena (growth stages); which ultimately determine annual plant development, and were used to recognize the individual growth rhythms inherent in plants. A phenological stage, such as full bloom or peak development, is a single point in development, whereas a phenological phase is the interval between two stages (Ruml and Vulic, 2005).

Data collected through a status monitoring technique yielded more information and insight into a species' phenology than data collected through event monitoring. Event-based monitoring, for example, typically misses recurring events (such as a second wave of blossoming within a season) (Crimmins *et al*., 2013).

Phenological event included first visible buds and flowers of the plant individuals. Many studies have used event data to document variations in spring leaf and flower emergence (Bradley *et al*., 1999; Inouye, 2008 and McKinney *et al*., 2012). Monitoring programs that recorded the timing of phenological events, that was, precisely defined moments in the annual life cycles of plants, were used in the past to observe stages of phenological phases (Sparks and Carey, 1995; Bradley *et al*., 1999; Fitter and Fitter, 2002; Miller-Rushing and Primack, 2008).

The work conducted in the UCD Putah Creek Reserve detailed budding phase which occurred in the axil of a leaf or at the tip of a stem, as a vegetative phenophase in which plant individuals develop buds, which are undeveloped or embryonic shoots. Buds are either specialized to produce flowers or short shoots, or they have the capacity to produce any type of shoot. The leaf phase was defined as beginning with the enlargement of the vegetative bud and ending with the fall of the leaves. Natural variation in deciduous plant leaf fall was assumed to represent an adaptation that allows plants living in seasonal environments to reduce water loss, herbivory, and damage during severe periods while increasing photosynthetic rates during less stressful seasons, according to observations (Karban R, 2007).

Study in tropical forest and grassland/thicket mosaic in Ghana showed that the duration of the fruiting phenophase in dry tropical trees was influenced, at least in part, by the time of blooming and the leafless period during the annual cycle. Longer-fruiting species flower in the hot, dry summer and capitalize on the rainy season for fruit development (Lieberman, 1982). Fruiting duration have imposed a constraint on flowering time since phenological events in tropical trees might have been dependent on preceding and subsequent stages (Fenner, 1998). Fruiting duration was related to blooming time, although fruit type was unrelated to flowering time, especially in species that flower in the dry season.

2.2. Description of *Securidata longepedunculata*

The epithet name 'longepedunculata' relates to the long peduncle that carries the blooms, while the genus name 'Securidaca' is related with the Latin word *'securis*' meaning hatchet (relating to the shape of the wing on the nut). The popular name for *Securidaca longepedunculata* is referred to as 'Violet Tree' (inspired by the violet colour of the blossoms). It is a small to medium-sized tree with pale grey smooth bark that grows up to an average of six metres in height. The alternately arranged leaves come in a variety of sizes and shapes, and they're commonly found in clusters or crowded on dwarf spur branchlets with spines (Van Wyk *et al*., 2009). The terminal and axillary bunches, which develop with the very young leaves, are around 30 - 50 mm long (Ndou, 2006).

When they're young, they have incredibly fine hairs, but as they become older, they lose them. Flowers are small, carried on long, slender stalks (approximately 10 mm long, pink to lilac or purple, and sweetly perfumed), and produced in short bunches in early summer. Between April and August, flowers grow into round fruit with a characteristic membrane wing (spreading up to 40 mm long) that is purple green while young and gradually becomes pale straw-coloured as they mature (Mustapha, 2013).

2.3. Distribution and habitat of *Securidata longepedunculata*

Securidaca longepedunculata is a tree that grows in a variety of temperatures, ranging from subtropical hot and arid to equatorial humid. It can be found in a wide range of environments, from semi-arid scrub to deep forest, as well as many woodland and bush habitats and gallery forests. It grows mostly in the tropical and subtropical habitat, from the northern part of South Africa to the north of Africa (Coates and Palgrave, 2005).

The tree can withstand bushfires but is susceptible to frostbite. It is present in practically all nations in Sub-Saharan Africa and is widely dispersed in tropical Africa. It occurs in the miombo woodland, bushland and forest edges in Tanzania (Stevenson, *et al*., 2009). It is most common in coastal forests embedded in acid and sandy or rocky soil type within altitude ranging from 0 - 1800 metres with mean annual rainfall ranging between 600 - 1000 millimetres (Ndou, 2006).

Securidaca longepedunculata grows in the North-West and Limpopo Provinces in South Africa. and it has been named '*mpesu'* by *Vhavenḓa* (people found occupying the far north part of Limpopo Province) reflecting on its aphrodisiac properties that makes the man who uses it to be so sexual virile to a point where the cloth worn covering his private part is always pushed away by stone hard male organ and that is referred in '*luvenḓa*' as '*u pesula*' hence that species is referred to as *'mpesu'* (Magwede *et al*., 2018).

This tree suffers from over-harvesting (especially in the Vhembe District along land scape occupied by *Vhaveṋḓa*) as is mainly thought after by *Vhaveṋḓa* for its aphrodisiac properties. Periodic droughts and bushfires additionally provide challenge in the propagation and survival of this tree (Ndou, 2006).

2.4. *Securidata longepedunculata* 's reproductive phenology and propagation

Securidaca longepedunculata has been critically endangered because of its high seed dormancy, low germination rate and overexploitation (Lijalem and Feyissa, 2020). Flowers bloom profusely during the start of the rainy season. Fruits linger on trees for months in May and June, and the ones that stay the longest were thought to germinate the best. Because the fruits normally hang on the tree for a year or more (it has been proposed that seed should not be sown until the tree was one-year-old), the seed appeared to lose viability quickly and germination was inconsistent. As a result, it was recommended that seeds be soaked in cold water for 24 hours before sowing, as treated seed has been shown to germinate faster than untreated seed (Mbuya *et al*., 1994).

Simple propagation strategies for *S. longepedunculata* were identified through *ex vitro* (natural environment) and *in vitro* (artificial environment) investigations. *Ex vitro* germination rates did not reach 43%, but *in vitro* techniques yielded germination rates of 67 to 90%. (Zulu *et al*., 2011). It was concluded that proper *in vitro* treatments could promote seed germination, shoot multiplication, and rooting of *S. longepedunculata*.

Seed coat removal, sulfuric acid, gibberellic acid, hot water, cold water, and control were all investigated for their effectiveness in improving *S. longepeduculata* seed germination in the field, laboratory, and greenhouse. The maximum germination rate was achieved by removing the seed covering. Under greenhouse settings, this pre-treatment resulted in 90 percent seed germination, compared to 63.3 percent in the laboratory, and 0 percent germination in untreated seeds cultivated in the wild. Pre-treatments with boiled and cold water had little effect on seed germination. The average seedling heights from diverse pre-treatments ranged from 4.5 cm to 22 cm, with the highest seedling (22 cm) coming from seed pre-treated with 400 mg/l gibberellic acid. The removal of the seed coat was found to be beneficial (Tiawoun *et al*., 2017).

2.5. Medicinal Uses of various organs of *Securidaca longepedunculata*

Securidaca longepedunculata is an African multipurpose medicinal plant that plays a significant role in both traditional and modern medicine (Mongalo *et al*., 2015). Some phytochemicals, such as alkaloids, cardiac glycosides, flavonoids, saponins, and tannins were responsible for the minor toxicity of *S. longepedunculata* root bark (Auwal *et al*., 2012). Alkaloids has been utilized for weaponry, especially arrow poisons in Africa (Neuwinger, 1998).

The uses of *S. longepedunculata* varied greatly; the tree's roots could be used to treat coughs, chest problems, toothaches, gout, fevers, constipation, diabetes, and microbiological infections in humans (Ajali and Chukwurah, 2004). It was also discovered that it has anti-inflammatory effects, which aid in the relief of arthritic aches (Okoli, 2006). *Securidaca longepedunculata* is a valuable plant species with prospective applications in the treatment of transmissible and infectious diseases such as malaria, tuberculosis, and infections caused by acquired bacteria (Mongalo *et al*., 2015).

If consumed in large quantities, the roots of *S. longepedunculata* might be hazardous. When a saponin present in the roots came into touch with blood, it caused haemolysis and pharmacologically severe damage to bone marrow (Stevenson *et al*., 2009). According to a thorough study in Angola, roots included 27 percent lipids and 0.36 percent protides, tannins, and steroids. Presenegenin, the deadly indole alkaloid securinine, and several ergot alkaloids were all produced by *Securidaca longepedunculata* (Stevenson *et al*., 2009). *Securidaca longepedunculata* roots contained methyl salicylate and saponin, which were discovered when the root was administered to a cat in an experiment (Watt and Breyer-Brandwijk, 1962).

Phenols, tannins, flavonoids, saponins, glycosides, steroids, terpenoids, quinones and fixed oil were found in leaf extract. To treat epilepsy, headaches, stomach aches, infertility, snakebite, toothache and to remove the placenta, the leaves were eaten fresh or taken orally and nasally (Augustino *et al*., 2011).

Alkaloids, tannins, flavonoids, terpenoids, and phenols were found in the flower extract. Significant DPPH free radical scavenging activity was found in leaf and floral extracts. Leaf extract contained 17.0867 0.268 mg Quercetin Equivalent/g extract, while total phenolics contained 22.73 0.04583 mg Gallic Acid Equivalent/g extract. The total flavonoid content of floral extract was determined to be 6.0 0.273 mg Quercetin Equivalent/g extract, whereas the total phenolics content was 18.17 0.017 mg Gallic Acid Equivalent/g extract. This revealed that the leaf and floral extracts of *S. longepedunculata* contained essential bioactive elements and exhibit potent *in vitro* antioxidant activity. As a result, these plant sections might be exploited to obtain essential pharmaceutical chemicals (Shemishere *et al*., 2020).

The entire plant is used to wash the mouth and treat illnesses including oral candidiasis, excessive coughing, and other opportunistic infections linked to the Human Immunodeficiency Virus (HIV) (Chinsembu and Hedimbi, 2010).

2.6. Other Products and Services of *Securidaca longepedunculata*

Securidaca longepedunculata is used in a variety of ways in different nations. The methanol extract and the methyl salicylate component from the plant's roots are combined to form a toxin that can be utilized for a variety of purposes. Poisons developed from *S. longepedunculata* are still used in tribal warfare in West Africa, not simply for hunting food and defending against wild animal predation (Neuwinger, 1998).

Pesticides made from *S. longepedunculata* could be ground into a fine powder and used to preserve stored grains. Methyl salicylate is a well-known plant stress signal that could also be used as an insect repellent. Methyl salicylate made up 90% of the volatile component of the roots of *S. longepedunculata*, which is uncommon in many other grains or legume seeds. In stored grains, a mixture of methanol extract and methyl salicylate created a highly effective natural insecticide against weevils and other insects. This was an essential alternative to synthetic pesticides for small-scale farmers in Africa who might lack the resources or funds to purchase synthetic pesticides (Stevenson *et al*., 2014). Traditional farmers in Ghana have leveraged their farming knowledge to improve grain storage practices using botanical insecticides, according to a report published by the Natural Resources Institute in the United Kingdom (Belmain and Stevenson, 2001).

When *S. longepedunculata* powder was added to weevil-infested grains, the damage caused by the weevils was decreased by 65 percent. The S. zeamais (maize weevil), Rhyzopertha Dominica, and Prostephanus truncates insects were the most likely to infest stored grains. According to the findings, the maize weevil could smell the odor of methyl salicylate and avoided it. It acted as an insect repellant as well as a toxin, reducing the quantity of female eggs in the grains. This kind of pesticide application was quite effective, and the grains could be stored for at least 9 months. This discovery gave a low-cost, natural alternative to petrochemical pesticides for some African small-scale farmers (Stevenson *et al*., 2014).

Securidaca longepedunculata roots or pounded seeds could be utilized as soap and bleaching materials. Inner bark of straight annual shoots yielded fine-quality fibre, which when retted could be used to make flax-like textiles. Because of its long, resilient, and resistant fibres, it was highly valued in Western, Central, and Southern Africa. It's used to make fishing net and line string and rope, as well as bird and animal snares, thread for sewing bark fabric and bead string for jewellery. Due to being termite and rot resistant poles, hut construction, arrows and brooms were all made from the wood (Van Wyk and Gericke, 2000).

2.7. Conservation status and challenges faced by *Securidaca longepedunculata*

Securidaca longepedunculata is an African medicinal plant with a long history in both traditional and modern medicine. Because of its high seed dormancy, low germination rate, and overexploitation, this plant was on the verge of extinction (Ndou, 2006). Despite the fact that *S. longepedunculata* is protected by provincial and national legislation in several countries, it was nevertheless one of Africa's most traded medicinal plants (Moeng, 2010; Tabuti *et al*., 2012). This plant has been adopted by Mali's Royal Botanical Gardens as part of their "Adopt a seed- preserve a species" campaign. Anyone could contribute to the purchase of a *S. longepedunculata* in order to aid local communities and safeguard the species. The Millennium Seed Bank Partnership was behind this program. (KRBG, 2013). In Burkina Faso, *Securidaca longepedunculata* and *Zanthoxylum zanthoxyloides* were already scarce in nature and sold for a high price on the market (Ouedraogo *et al*., 2020).

Securidaca longepedunculata is a protected plant in South Africa, according to the National Forest Act of 1998. The fact that the roots were a target for those who used this plant made it difficult for it to endure repeated harvesting. Globally, the demand for medicinal plants expanded at such a rapid rate that the world's natural sources were being depleted. Hundreds of species have been overharvested and were on the verge of extinction unless they were preserved or cultivated. All stakeholders in Africa should work together to start a conservation effort to prevent this plant from becoming endangered or extinct. Furthermore, there has been minimal coordination on medicinal plant conservation between government agencies, environmental organizations, and the rural community. As a result, establishing an integrated structure among the parties participating in traditional medicine research was critical. This was to ensure adequate coordination in the management of medicinal plant resources and their long-term use (Musila *et al*., 2002).

CHAPTER 3: MATERIALS AND METHODS

3.1. Study Area

The project was conducted at the Nylsvley Nature Reserve, Limpopo Province, South Africa. Nylsvley Nature Reserve is a 40 km^2 protected area, lying on the seasonally-inundated floodplain of the Nyl River, the uppermost section of the Mogalakwena River which has a very shallow gradient. It is located near Mookgophong in the Limpopo Province of South Africa.

Because of its international conservation value, this region has been designated as a Ramsar wetland site. The floodplain is flanked by open woods and is made up of vast reedbeds and grassveld. Nylsvley Nature Reserve is located on a level to gently sloping plain between 1080 and 1140 m.a.s.l. and covers 3120 ha of mixed Bushveld (Acocks,1953). The average annual rainfall is 630 millimeters, and the average annual temperature is 19.0 degrees Celsius (Scholes and Walker,1993). The farm Nylsvley 560 KR is located on the Springbok Flats, 10 kilometers south of Mookgophong in the Limpopo Province of South Africa (240 36'-240 42' S, 28040'-28044' E). Maroelakop (1140 m) in the south-west and Stemmerskop (1090 m) slightly west of the former are noteworthy.

The Nyl River, which flows from south-west to north-east in a narrow valley, divides the area. With the exception of Maroelakop and Stemmerskop, which are created by sandstones from the Waterberg System, the land to the south and east is essentially sandy. The land to the west and north, notably along the flat country flanking the Nyl River, is underlain by loam or clay. The Nylsvley area in South Africa is one of the world's most carefully researched savanna habitats, making it a valuable source of data and theory on this vital tropical ecosystem (Scholes and Walker, 1993). The study area was demarcated into three sections namely: section A, section B and section C. The demarcation followed the inroads from west side to the east side and from the north to south side. *Securidaca longepedunculata* were identified on the GPS of South Africa at (24.653717 – 24.685794 S, 28.690508- 28.727298 E).

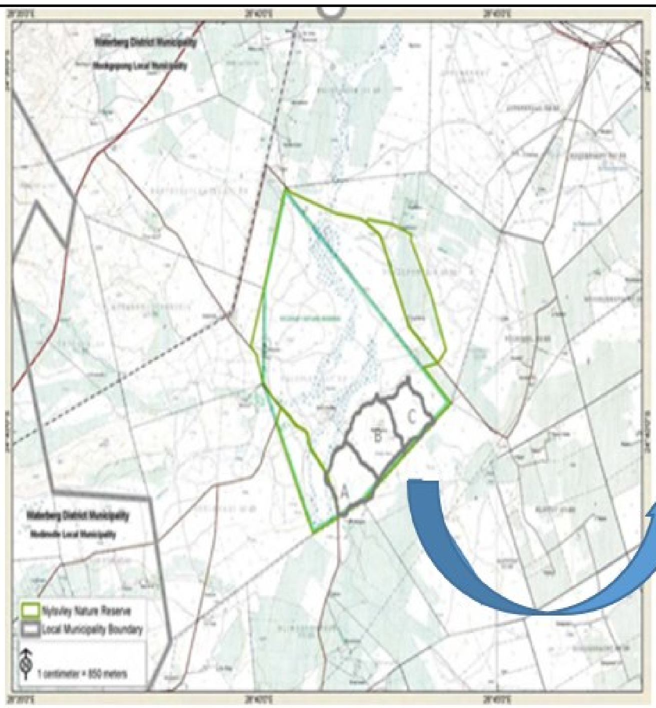

Figure 3.1: Nylsvley Nature Reserve's location map (LEDET, 2013) showing sections marked A, B and C where S. longepedunculata plants were identified.

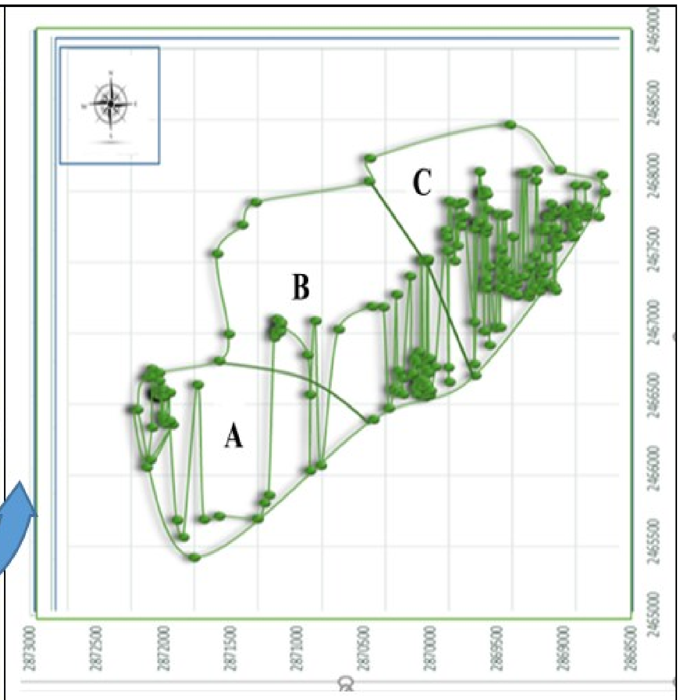

Figure 3.2. The demarcated study site of Nylsvley Nature Reserve (as indicated in Figure 3.1) showing position of each of 200 *S. longipedunculata* plant individuals on Nylsvley Nature Reserve map with the scale of one co-ordinate on the map equivalent to 0.00001 coordinate on the ground.

3.2. Sampling

Two hundred *S. longepedunculata* plant individuals were sampled within the sections marked A, B and C on the provided maps (Figures 3.1 and 3.2). All *S. longepedunculata* plant individuals found outside the demarcated sections were not sampled. All identified and selected *S. longepedunculata* were allocated numbers and recorded during registration.

3.3. Data Collection

Data was collected on individual plants identified using Global Positioning Systems coordinates. The co-ordinates for each individual plant was recorded using Global Positioning System (GPS) navigation application found in HUAWEI p30 smart phone. This made it possible for easy identification of each individual plant as the exact GPS latitude and longitude coordinates positions of each identified *S. longepedunculata* were considered for each successive visit. Data was collected on the GPS of South Africa at (24.653717 – 24.685794 S, 28.690508- 28.727298 E). A map indicating geographical position of each sampled *S. longepedunculata* plant individual was constructed as indicated in Figure 3.2. The reserve was demarcated or divided into three sections (A, B and C) as indicated in Figure 3.1.

A total of 200 *S. longepedunculata* plant individuals were identified and marked using a permanent ink marker. A total of forty (40) plants were identified and recorded in section A. Sixty-six (46) individual plants were recognized and recorded in section B. A total of 114 unique plants were discovered and recorded in section C. The shaky map of the Global Positioning System was created (Figure 3.2). The majority of plant individuals were found in the research area's section C. (Figure 3.2).

3.4. Observation of phenological phases and stages.

The phenological data was mainly collected through direct ground-based observations. The data was collected following a data sheet attached as an appendix. The observation was made as part of a novel data processing pipeline that was used to create a massive dataset of phenology data from North America and Europe (Stucky *et al*., 2018). Only visual observations of several phenological stages were carried out in this study. Over the course of two years, 200 *S. longepedunculata* plant individuals were observed *in situ* and thorough qualitative observations were made. The observations were made based on morphological traits as stated in productivity studies by phenology (Lieth, 1973).

Vegetative phenophase

During this phenophase, only budding and developmental stages of leaves were considered. For budding, only the time of presence of buds was recorded. For leafing, the time for presence and intensity of leaf greening, leaf yellowing and leaf shedding was recorded. Each developmental stage was measured to determine when it started (onset stage), when it was at its maximum (peak stage) and lastly when it declines (decline stage). Observations for each stage was recorded in percentage form (Appendix A). The record was based on presence of an observation for a specific phase and stage as either compared with the presence of other phases and stages based on a scale ranging from zero (0) to 100%, with the record of zero percent (0%) indicating the absence of a phase and/or stage and above 50% indicating the peak or full intensity of stage in a phase. For leafing 100% was given for the presence of each phase and stage looking at leaves that are green, leaves turning yellowish and those that dropped to the ground, if leaf greening is given 70%, the rest of 30 % is shared between leaf yellowing and leaf shedding.

3.5. Reproductive phenophase

During reproductive phenophase, only flowering and developmental stages of fruit were considered or observed. For flowering, only the time of presence of flowers was recorded. For fruit development, time for presence and intensity of unripe fruits, ripe fruits and dissemination of ripe fruits or seeds were recorded. For fruit development, the same observation as in leaf development was employed. Each developmental stage was measured to determine when it started (onset stage), when it was at its maximum (peak stage) and lastly when it declines (decline stage). Observations for each stage was recorded in percentage form (Appendix A). The record was based on presence of an observation for a specific phase and stage as either compared with the presence of other phases and stages based on a scale ranging from zero (0) to 100%, with the record of zero percent (0%) indicating the absence of a phase and/or stage and above 50% indicating the peak or full intensity of stage in a phase. For fruiting 100% was given for the presence of each phase and stage looking at fruits that are unripe, fruits that are ripe and those that dropped to the ground, if unripe fruits are given 55%, the rest of 45 % is shared between ripe fruits on the tree and those on the ground.

The data recorded was analysed considering time of presence within a specific season for example, if the stage was present in July, such will fall under late winter season. Correlation between phenological phase and seasonal pattern were observed and recorded.

CHAPTER 4: RESULTS

Phenological phases and stages of *S. longepedunculata* observed in the time of the year they occur at Nylsvley Nature are reported on the data sheet calendars below (Tables 4.1 and 4.2)

4.1. Vegetative phenophase.

During this stage, budding was observed between September and November 2018 (mid spring to early summer) respectively. The picture in Figure 4.1.1 was taken in October 2018 when budding was progressing.

Figure 4.1.1 Picture showing budding phenophase of *Securidaca longepedunculata* taken in October 2018.

Leaf greening, leaf yellowing and leaf shedding were all recorded as reflected in table 4.1 below.

Leaf greening was observed from September 2018 to July 2019 (mid spring 2018 to late winter 2019). The onset of leaf greening was observed in September with 15% (low level of intensity). The peak development stage of leaf greening was observed from October 2018 to February 2019 (late spring 2018 to early autumn 2019) with average of 72% (high level of intensity). The picture in Figure 4.1.2 below was taken in early November 2018 when leaf greening was at its early peak stage.

Figure 4.1.2. Picture showing early peak stage of leaf greening phenophase of *Securidaca longepedunculata* taken in November 2018.

The decline stage of leaf greening was observed from March to July 2019 (mid-autumn to late winter). In August, almost all *S. longepedunculata* plant individuals have very few or no green leaves (Figure 4.1.5).

Leaf yellowing was observed from January to July 2019 (late summer 2019 to late winter 2019). The onset of leaf yellowing was observed in January 2019 with 25% (low level of intensity). The peak development stage of leaf yellowing was observed between May and June with average of 55% (high level of intensity). The peak stage was more dominant in May 2019 as indicated in Figure 4.1.3.

Figure 4.1.3. Picture showing peak stage of leaf yellowing phenophase of *Securidaca longepedunculata* taken in May 2019.

The decline stage of leaf yellowing was observed in July 2019 (late winter). In August, most of *S. longepedunculata* plant individuals were having few or no yellow leaves as almost all had dropped to the ground (Figure 4.1.5).

Leaf shedding was observed throughout the year. Leaf shedding was mainly observed by considering leaves dropped on the ground as indicated by the picture which was taken in July 2019 (Figure 4.1.4).

Figure 4.1.4 Picture showing leaf shedding phenophase of *Securidaca longepedunculata* taken in July 2019.

The presence of leaves observed on the ground was at 25% as of January 2019 (low level of intensity) progressing to March 2019. The peak development stage of leaf shedding was observed in July 2019 (late winter) and August 2019(early spring) at an average of 80 % (high level of intensity). The decline stage of leaf shedding was observed from September 2019 with an average of 5%.

In August 2019, most of *S. longepedunculata* plant individuals were left with very few or no leaves with most dropped to the ground. The peak stage was more dominant in August 2019 as indicated in Figure 4.1.5.

Figure 4.1.5 Picture showing leaf dormancy stage of *Securidaca longepedunculata* taken in August 2019.

Table 4.1. Data sheet calendar showing *Securidaca longepedunculata* leaf phenological phases as well as the intensity of each stage as they have occurred at Nylsvley Nature Reserve.

Phenophases			Autumn			Winter			Spring			Summer	
		Late summer	Early	Mid	Late	Early	Mid	Late	Early	Mid	Late	Early	Mid
		Month of occurrence (01 September 2018 – 31 August 2019)											
		Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Vegetative Phenophase	Bud development	**0 %**	**0 %**	**0 %**	**0 %**	**0 %**	**0 %**	**0 %**	**0 %**	Present	Present	Present	**0 %**
	Leaf greening	**50%**	**50%**	**35 %**	**25 %**	**5 %**	**5 %**	**5 %**	**5 %**	**15 %**	**80%**	**90 %**	**90 %**
	Leaf yellowing	**25%**	**25%**	**35 %**	**45 %**	**60 %**	**50 %**	**25%**	**5 %**	**5 %**	**5 %**	**5 %**	**5 %**
	Leaf shedding	**25%**	**25%**	**30 %**	**30 %**	**35 %**	**45 %**	**70 %**	**90 %**	**5 %**	**5 %**	**5 %**	**5 %**

4.2. Reproductive phenophase

During this stage, flowering was observed between September 2018 and January 2019 (mid spring to late summer). Figure 4.2.1 indicate how the flowers looked like in October 2018.

Figure 4.2.1 Picture showing flowering phenophase of *Securidaca longepedunculata* taken in October 2018.

Fruiting was recorded as indicated from the table below (Table 4.2).

Unripe fruits were observed from October 2018 to February 2019 (mid spring 2018 to early summer 2019). The onset of unripe fruits was observed in October with 25% (low level of intensity). The peak development stage of unripe fruits was observed in November and December 2018 (summer) with average of 87.5% (high level of intensity). Figure 4.2.2 shows the picture of unripe fruits taken in November 2018.

Figure 4.2.2 Picture showing unripe fruits of *Securidaca longepedunculata* taken in November 2018.

The decline stage of unripe fruits was observed from March to July 2019 (mid-autumn to late winter). In August most (98%) of *S. longepedunculata* plant individuals had no unripe fruits (Figure 4.2.5).

Ripe fruits were observed from December 2018 to July 2019 (mid-summer to late winter). The onset of ripe fruits was observed in December 2018 with 25% (low level of intensity). The peak development stage of ripe fruits was observed in March and April 2019 (autumn) with average of 75% (high level of intensity). Figure 4.2.3 shows the picture of ripe fruits taken in April 2019.

Figure 4.2.3 Picture showing ripe fruits of *Securidaca longepedunculata* taken in April 2019.

The decline stage of ripe fruits was observed from May to July 2019 (winter). In August, most (80%) of *S. longepedunculata* plant individuals had no ripe fruits (Figure 4.2.5).

Seed shedding was observed from March to July 2019 (mid-autumn to late winter). The onset of seed shedding was observed in March and April 2019 with 15% (low level of intensity). The peak development stage of seed shedding was observed from May (early winter) to August 2019 (early spring) with average of 67.5% (high level of intensity). Figure 4.2.4 shows the picture of shed ripe fruits taken in July 2019.

Figure 4.2.4 Picture showing seed shedding phenophase of *Securidaca longepedunculata* taken in July 2019.

The decline stage of seed shedding was observed in August where in spring most of *S. longepedunculata* plant individuals have shed all their seeds. The peak stage was more dominant in early September 2018 as indicated in Figure 4.2.5.

Figure 4.2.5 Picture showing *Securidaca longepedunculata* without seeds and was taken in early September 2018.

Table 4.2. Data sheet calendar showing *Securidaca longepedunculata* fruit phenological stages as well as the intensity of each stage as they have occurred at Nylsvley Nature Reserve

Phenophases			Autumn			Winter			Spring			Summer	
		Late summer	Early	Mid	Late	Early	Mid	Late	Early	Mid	Late	Early	Mid
		Month of occurrence (01 September 2018 – 31 August 2019)											
		Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Reproductive Phenophase	Flowering	Present	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	Present	Present	Present	Present
	Unripe Fruit	**50%**	**50%**	**10%**	**10 %**	**5 %**	**5 %**	**5%**	**0 %**	**0 %**	**25%**	**100 %**	**75 %**
	Ripe Fruit	**50%**	**50%**	**75 %**	**75 %**	**45 %**	**35 %**	**35 %**	**5 %**	**0 %**	**0 %**	**0 %**	**25 %**
	Seed shedding	**0%**	**0%**	**15 %**	**15 %**	**55 %**	**60 %**	**65 %**	**95 %**	**0 %**	**0 %**	**0 %**	**0 %**

.

CHAPTER 5: DISCUSSION

5.1. Vegetative phenophase.

Time of budding was observed from mid spring in September 2018 and continued until early summer in November 2018 (Figure 4.1). The presence of buds in *S. longepedunculata* individual plants occurred for three months in spring and in a similar way such was observed in Norway on 20 species of deciduous trees (Nordii *et al*., 1980). Certain environmental circumstances, such as air and soil temperature thresholds, encourage vegetative activity such as budding, which must first be overcome in order to promote growth (Larcher, 1980). Typically, growth is accompanied with changes in the individual's expression, most notably an increase in the width, weight, and volume of its parts (Puchalski, 1969). Literal transition from young to mature plants is correlated to increase in size of shoot apical meristem (Allsopp, 1968), as such more buds were expected on long matured than short young adult *S. longepedunculata* individual plants. However, though statistically non-significant, by simple direct observation on *S. longepedunculata* individual plants, short young adults were sprouting more than long mature adult individual plants. This could be because short young plants are easily and directly accessed for observation of their branches as compared to very tall and mature adults plant individuals.

Leaf greening was recorded from mid spring in September 2018 to early spring in August 2019. Green leaves started as small young leaves to fully developed mature leaves and from few to many leaves on the branches of *S. longepedunculata*. The presence of these leaves was recorded for almost twelve (12) months of the year in most of *S. longepedunculata* plant individuals, whereas some few individuals (about 10%) retained some of their green leaves throughout the year. This few individual plants retained 5% of their leaves from May 2019 to August 2019 (Table 4.1). This phenomenon was also observed in *Vitellaria paradoxa* subsp. *nilotica* in savanna parklands in Uganda, in which old mature green leaves continued to appear or persist on the shoots during the leaf-fall period (Okullo, 2003). The decline stage of leaf greening was observed from mid-autumn in March 2019 to late winter in July 2019, which is expected because winter is the dormant period where plants lose their leaves. Accordingly, in August most of *S. longepedunculata* plant individuals had no green leaves.

Securidaca longepedunculata green leaves begun to discolour by mid-summer in December 2018. This could be due to old leaves that remain during leaf fall in the previous phenological life cycle. These leaves continue to fall until February 2019. The actual leaf yellowing onset is in autumn around March 2019 and continues to reach the peak in the middle of winter (May and June 2019) and later declined in late winter (July 2019) when leaves started to fall off. In early spring in August 2019 most *S. longepedunculata* individual plants lost their leaves and looked dry and dormant. The loss of leaves by these plants was probably due to windy conditions that sometimes prevail in August in the Nylsvley Nature Reserve.

Leaf shedding of *S. longepedunculata* was recorded throughout the year. It slowly took place from November 2018 to February 2019, then increase in autumn and reaches the peak by late winter in July 2019. Leaf shedding later decline by early spring in August 2019, where most (90%) of *S. longepedunculata* plant individuals have shed all their mature dry leaves. Leaf fall seasonality was observed in *S. longepedunculata* throughout the course of two years of observation, implying that they are susceptible to the same restrictions and triggering variables that affect other plants.

5.2. Reproductive phenophase.

Most *S. longepedunculata* individuals reached their flowering peak development stage between September 2018 and January 2019, with a peak in November 2018 (Table 4.2). Flowering records were not made in a complex manner, but rather simply based on the existence of flowers, as suggested by a long tradition of recording seasonal occurrences with little need for specialized equipment or experience (Whitfield, 2001). Most *S. longepedunculata* flowering phenophases and development stages correlate to the flowering patterns of woody species in Botswana (Miller, 1949), Tanzania (Scott, 1934), and Malawi savanna trees (Hall-Martin and Fuller, 1975). Flowering duration of *S. longepedunculata* differed per individual plants, it lasted for about three months and expanded or ranged to five months across all different individuals of the same species in the current study. Multiple flowering stages or peaks have also been observed in Ghana (Ewusie, 1968), Botswana (Miller, 1949), South West Africa (Rutherford, 1975), and Costa Rica (Opler *et al*., 1980).

It has been proposed that the influence of differences in the rainfall pattern on the commencement of the flowering phase might be attributed to more than one flowering phase in a season or the absence of a flowering phase in a season (Opler *et al*., 1976). Rainfall may have played a role, as previously stated, but it's also plausible that plants struggled with energy allocation, particularly after a year of extraordinarily bountiful flowering and fruit output (Barbour *et al*., 1980). These could have also yield in the flowering differences observed in different individual plants of *S. longepedunculata* on the *in situ.* Some flowers produced during the rainy season were aborted (Figure 5.2).

Figure 5.2. Picture taken on 20th of December 2018 during rainy days showing the fall out (abort) of the young flower of *Securidaca longepedunculata.*

There was quite an overlap of fruiting phenophase due to different sizes of plants, type of soil and congestion of trees where individual plants were observed. Unripe fruits were recorded from mid spring in October 2018 to early summer in February 2019, while ripe fruits lasted from mid-summer in December 2018 to late winter in July 2019, but became more visible between March 2019 at average of 75% until August 2019 at average of 5% (Table 4.2). According to other research, the purplish green young fruits of *S. longepedunculata* become pale straw coloured between April and August (Mustapha, 2013). The slight differences in the timing of fruits ripening between the current study and one by Mustapha in 2013 was probably due to difference in environmental conditions between the study areas.

Fruit shedding occurs from mid-autumn in March 2019 to late winter in July 2019, causing seed dormancy and ensuring that some seeds are available for germination once the wet season begins. Because of the considerable changes in biotic and abiotic variables between the dry and rainy seasons, fruit maturity and appropriate conditions for dispersal are closely coordinated in tropical dry forests (Griz and Machado, 2001).

CHAPTER 6: CONCLUSION

In conclusion, the study had been able to achieve its objectives by providing data with regard to the onset, peak development, duration of the phenophase and correlation to environmental or climatic conditions. The majority of phenological change investigations have been geographically and taxonomically restricted. Other studies used a variety of methods, such as different categories and definitions for various phenological stages, different criteria for determining the presence of such stages, different sampling methods and frequencies, different units of observation, making cross-study and species comparisons difficult (Root et al. 2003).

The majority of traditional phenological observations were qualitative in the past (e.g., phenophase descriptions based on intensity level rather than direct counting); more recently, a quantitative approach has been stressed (Gill and Mahall, 1986.).Quantitative approach such as phenometry which is the phenological specialty area that monitors the progressive growth of plants by continuous measurement, for example the use of mounted standard digital camera providing hourly images that are later analysed (Ahrends *et al.*, 2008). Sometimes these measurements are also possible through observations by eye or by other simple means, e.g. such as determination of the daily length growth of leaf size or shoot elongation during the time of shooting using a tape measure (Schnelle, 1955). Phenometry will undoubtedly have a significant impact on future efficiency investigations (Lieth, 1973).

However, additional research could rearrange phenophases to include a leaf phase that begins with vegetative bud swelling and ends with leaf fall; a flowering stage that begins with flower bud swelling and ends with withered flower; and a fruiting phase that begins with the presence of unripe fruit and ends when dissemination stops. To improve our comprehension of the patterns of the sampled S. longepedunculata plant individuals, we observed the presence or absence of leaves, flowers, and fruit on certain unmarked individuals. Starting with bud hibernation and concluding with fruit ripening, different phases and stages of the yearly growth cycle were recognized.

This phenology investigation may necessitate long-term observation of the same individuals. If monitoring is done for a given phenophase, some studies may only have considered a few months. Short-term studies reduce the ability to discern changes in phenological patterns' seasonality as a result of environmental changes. Understanding these interactions is especially important in a seasonal setting like Nylsvley Nature Reserve.

Changes in the phenology of species as a result of environmental changes result in changes at the community level. In the Nylsvley Nature Reserve, intense and extended droughts, large rainfall, and fires of various intensities can be seen. Changes in vegetation structure are caused by several variables. As an adaptive reaction to new conditions, the frequency and intensity of those occurrences might change phenological patterns. Phenology can be linked to a range of characteristics at Nylsvley Nature Reserve, including water availability, wood density, the frequency and duration of reproductive events and interspecific interactions. A comprehensive study of phenological patterns with the greatest number of species possible is required to anticipate plant behavior in terms of abundance and dispersion. In addition, plant communities must be assessed for their ability to maintain herbivore and frugivorous animals (Scott and Martin 1984). Finally, understanding phenology contributes to good reserve management and plant species protection.

REFERENCES

1. Acocks, J.P.H., 1953. Veld types of South Africa., *Veld types of South Africa.* 28, pp. 1-12.
2. Adeyemi, O.O., Akindele, A.J., Yemitan, O.K., Aigbe, F.R. and Fagbo, F.I., 2010. Anticonvulsant, anxiolytic and sedative activities of the aqueous root extract of *Securidaca longepedunculata* Fresen. *Journal of Ethnopharmacology*, 130(2), pp.191-195.
3. Ahas, R. and Aasa, A., 2003. Developing Comparative Phenological Calendars. *An Integrative Environmental Science*. vol 39, pp 301-318.
4. Ahrends, H.E., Brügger, R., Stöckli, R., Schenk, J., Michna, P., Jeanneret, F., Wanner, H. and Eugster, W., 2008. Quantitative phenological observations of a mixed beech forest in northern Switzerland with digital photography. *Journal of Geophysical Research: Biogeosciences*, 113(G4).
5. Ajali, U. and Chukwurah, B.K.C., 2004. Antimicrobial activity of *Securidaca longipedunculata. Phytomedicine*, 11(7-8), pp.701-703.
6. Allsopp, A., 1967. Heteroblastic development in vascular plants. *Advances in morphogenesis.* 6, pp.127-171.
7. Augustino, S., Hall, J.B., Makonda, F.B. and Ishengoma, R.C., 2011. Medicinal resources of the Miombo woodlands of Urumwa, Tanzania: plants and its uses. *Journal of Medicinal Plants Research.* 5, 6352–6372.
8. Auwal, S.M., Atiku, M.K., Wudil, A.M. and Sule, M.S., 2012. Phytochemical composition and acute toxicity evaluation of aqueous root bark extract of Securidaca longipedunculata (Linn). *Bayero Journal of Pure and Applied Sciences*, 5(2), pp.67-72.
9. Ayensu, E.S., 1981. Assessment of threatened plant species in the United States. *Biological aspects of rare plant conservation*.
10. Barbour, M.G., Burk, J.H. and Pitts W.D., 1980. Terrestrial plant ecology Menlo Park, Calififornia.
11. Belmain, S. and Stevenson, P., 2001. Ethnobotanicals in Ghana: reviving and modernising age-old farmer practice. Pesticide outlook.
12. Belmain, S. R., Neal, G.E., Ray, D.E. and Golob, P., 2000. Insecticidal and vertebrate toxicity associated with ethnobotanicals used as post-harvest protectants in Ghana. *Food and Chemical Toxicology*. Volume 39, Pages 287-291.
13. Bradley, N.L., Leopold, A.C., Ross, J. and Huffaker, W., 1999. Phenological changes reflect climate change in Wisconsin. *Proceedings of the National Academy of Sciences*, 96(17), pp.9701-9704.

14. Burkill, H.M., 1985. The useful plants of west tropical Africa, vol. 1 *royal botanic gardens, kew.* Google Scholar.

15. Chinsembu, K.C. and Hedimbi, M., 2010. An ethnobotanical survey of plants used to manage HIV/AIDS opportunistic infections in Katima Mulilo, Caprivi region, Namibia. *Journal of ethnobiology and ethnomedicine*, 6(1), 25.

16. Coates-Palgrave M., 2005. Keith Coates Palgrave Trees of Southern Africa, Third Edition Struik Publishers, Cape Town, pp. 458–459.

17. Collinson, M. and Sparks, T., 2008. Phenology-Nature's calender: An overview of results from the UK phenology network. *Arboricultural journal*.vol 30, page 271-278.

18. Cosmulescu, S. and Bîrsanu Ionescu, M., 2018. Phenological calendar in some walnut genotypes grown in Romania and its correlations with air temperature. *International journal of biometeorology*, 62(11), pp.2007-2013.

19. Crimmins, T.M., Crimmins, M.A. and Bertelsen, C.D., 2013. Spring and summer patterns in flowering onset, duration, and constancy across a water‐limited gradient. *American Journal of Botany*, 100(6), pp.1137-1147.

20. Dery, B.B., 1999. Indigenous knowledge of medicinal trees and setting priorities for their domestication in Shinyanga Region, Tanzania. World Agroforestry Centre.

21. Drury, W.H., 1974. Rare species. *Biological conservation*, 6(3), pp.162-169.

22. Ewusie, J.Y., 1968. Preliminary studies on the phenology of some woody species of Ghana. *Ghana Journal of Science*, (3/4): 126-133.

23. Fenner, M., 1998. The phenology of growth and reproduction in plants. *Perspectives in Plant Ecology, Evolution and Systematics*, 1(1), pp.78-91.

24. Fitter, A.H. and Fitter, R.S.R., 2002. Rapid changes in flowering time in British plants. Science, 296(5573), pp.1689-1691.

25. Gabriel, E.I., Ebere, I.T., Onyema, E.I., Adaku, E.T., Uchenna, E.U., Nwabuisi, O.C. and Otah, A.A., 2015. Evaluation of Methanol Root Extract of Securidaca longipedunculata for Antitrypanosomal Activity in vitro and in vivo. *Thai Journal of Pharmaceutical Sciences*, 39(4).

26. Galeffi, C., Federici, E., Msonthi, J.D., Marini-Bettolo, G.B. and Nicoletti, M., 1990. New xanthones from Ectiadiopsis oblongifolia and Securidaca longipedunculata. *Fitoterapia*, 61(1), pp.79-81.

27. Gidey, M., Beyene, T., Signorini, M.A., Bruschi, P. and Yirga, G., 2015. Traditional medicinal plants used by Kunama ethnic group in Northern Ethiopia. *Journal of Medicinal Plants Research*, 9(15), pp.494-509.

28. Gilges, W., 1955. Some African poison plants and medicines of Northern Rhodesia (No. 11). Rhodes-Livingstone Museum.

29. Gill, D.S. and Mahall, B.E., 1986. Quantitative phenology and water relations of an evergreen and a deciduous chaparral shrub. *Ecological Monographs,* 56(2), pp.127-143.

30. Gray, R.E. and Ewers, R.M., 2021. Monitoring forest phenology in a changing world. *Forests*, 12(3), p.297.

31. Griz, L.M.S. and Machado, I.C.S., 2001. Fruiting phenology and seed dispersal syndromes in caatinga, a tropical dry forest in the northeast of Brazil. *Journal of tropical Ecology,* 17(2), pp.303-321.

32. Hall-Martin, AJ & Fuller, N.G., 1975. Observations on the phenology of some trees and shrubs of the Lengwe National Park, Malawi. *South African Journal of Wildlife Research-24-month delayed open access*, 5(1), pp.83-86.

33. Hedimbi, M. and Chinsembu, K.C., 2012. Ethnomedicinal study of plants used to manage HIV/AIDS-related disease conditions in the Ohangwena region, Namibia. *International Journal of Medicinal Plants Research*, 1(1), pp.4-11.

34. Inouye, D.W., 2008. Effects of climate change on phenology, frost damage, and floral abundance of montane wildflowers. *Ecology*, 89(2), pp.353-362.

35. Kallarackal, J. and Renuka, R., 2014. Phenological implications for the conservation of forest trees. *Plant reproductive biology and conservation. IK International, Delhi*, pp.90-109.

36. Karban, R., 2007. Deciduous leaf drop reduces insect herbivory. *Oecologia*, 153(1), pp.81-88.

37. Karou, S.D., Tchacondo, T., Tchibozo, M.A.D., Anani, K., Ouattara, L., Simpore, J. and De Souza, C., 2012. Screening Togolese medicinal plants for few pharmacological properties. *Pharmacognosy research*, 4(2), p.116.

38. KRBG., 2013. Help Us Save African Violet Tree, Support Kew. Kew Royal Botanical Gardens.

39. Kruckeberg, A.R. and Rabinowitz, D., 1985. Biological aspects of endemism in higher plants. *Annual Review of Ecology and Systematics.* (16): 447–479.

40. Larcher, W., 1980. Physiological plant ecology. 2nd totally revised edition.

41. Leith H. 1973. Analysis of temperate forest ecosystem. Springer.

42. Lieberman, D., 1982. Seasonality and phenology in a dry tropical forest in Ghana. *The Journal of Ecology*, pp.791-806.

43. Lijalem, T. and Feyissa, T., 2020. In vitro propagation of Securidaca longipedunculata (Fresen) from shoot tip: an endangered medicinal plant. *Journal of Genetic Engineering and Biotechnology,* 18(1), pp.1-10.
44. Magwede, K., Van Wyk, B.E. and Van Wyk, A.E., 2019. An inventory of Vhavenḓa useful plants. South African Journal of Botany, 122, pp.57-89.
45. McKinney, A.M., CaraDonna, P.J., Inouye, D.W., Barr, B., Bertelsen, C.D. and Waser, N.M., 2012. Asynchronous changes in phenology of migrating Broad-tailed Hummingbirds and their early-season nectar resources. Ecology, 93(9), pp.1987-1993.
46. Mbuya, L.P., Msanga, H.P., Ruffo, C.K., Birnie, A. and Tengnäs, B., 1994. Useful trees and shrubs for Tanzania: identification, propagation and management for agricultural and pastoral communities. RSCU-Swedish International Development Authority, English Press.
47. Meyer, J.M., Rakuambo, N.C. and Hussein, A.A., 2008. Novel xanthones from Securidaca longepedunculata with activity against erectile dysfunction. Journal of Ethnopharmacology, 119(3), pp.599-603.
48. Miller, C.B., 1949. Flowering periodicity in some woody plants of the Southern Bechuanaland Protectorate. *The Journal of South African Botany*, 15, pp.49-54.
49. Miller-Rushing, A.J. and Primack, R.B., 2008. Global warming and flowering times in Thoreau's Concord: a community perspective. Ecology, 89(2), pp.332-341.
50. Moeng, T.E., 2010. An investigation into the trade of medicinal plants by muthi shops and street vendors in the Limpopo province, South Africa (Doctoral dissertation).
51. Mongalo, N.I., McGaw, L.J., Finnie, J.F. and Van Staden, J., 2015. *Securidaca longipedunculata* Fresen (Polygalaceae): A review of its ethnomedicinal uses, phytochemistry, pharmacological properties and toxicology. *Journal of Ethnopharmacology*, 165, pp.215-226.
52. Mudau, T.E., Olowoyob, J.O. and Amooacd, S.O., 2021. Ethnobotanical assessment of medicinal plants used traditionally for treating diabetes in Vhembe district, Limpopo Province, South Africa.
53. Musa, A.A., Oyewale, A.O., Ndukwe, I.G., Yakubu, S.E. and Abdullahi, M.S., 2013. Phytochemical screening and antimicrobial activity of solvent fractions of Securidaca longepedunculata (Fresen) root bark methanol extract. *Journal of Chemical and Pharmaceutical Research*, 5(10), pp.28-33.

54. Musila, W., Kisangau, D. and Muema, J., 2002. Conservation status and use of medicinal plants by traditional medical practitioners in Machakos District, Kenya. *National Museums of Kenya*, 22, pp.12-18.
55. Mustapha, A.A., 2013. Ethno-medico-botanical uses of Securidaca longepedunculata Fresen (family-polygalaceae) from Keffi local government, Nasarawa state, Nigeria. *Journal of natural remedies*, 13(2), pp.133-137.
56. Ndamitso, M.M., Tijani, J.O. and Idris, S., 2013. Phytochemical and antibacterial activity of Securidaca longepedunculata on selected pathogens. *African journal of microbiology research*, 7(50), 5652-5656.
57. Ndou, A.P., 2006. Securidaca longepedunculata Fresen (Polygalaceae).
58. Neuwinger, H.D., 1998. Alkaloids in arrow poisons. *In Alkaloids* (pp. 45-84). Springer, Boston, MA.
59. Nordli, Ø., Wielgolaski, F.E., Bakken, A.K., Hjeltnes, S.H., Måge, F., Sivle, A. and Skre, O., 2008. Regional trends for bud burst and flowering of woody plants in Norway as related to climate change. *International Journal of Biometeorology*, 52(7), pp.625-639.
60. Ojewole, J.A.O., 2008. Analgesic, anti-inflammatory and hypoglycaemic effects of Securidaca longepedunculata (Fresen.)[Polygalaceae] root-bark aqueous extract. Inflammopharmacology, 16(4), pp.174-181.
61. Okoli, C.O., Akah, P.A. and Ezugworie, U., 2006. Anti-inflammatory activity of extracts of root bark of Securidaca longipedunculata Fres (Polygalaceae). *African Journal of Traditional, Complementary and Alternative Medicines*, 3(1), pp.54-63.
62. Okullo, J.B.L., Hall, J.B. and Masters, E., 2003. Reproductive biology and breeding systems of Vitellaria paradoxa. *Improved Management of Agroforestry Parkland Systems in Sub-Saharan Africa. EU/INCO Project Contract IC18-CT98-0261, Final Report, University of Wales Bangor*, UK, pp.66-84.
63. Oni, P.I., Jimoh, S.O. and Adebisi, L.A., 2014. Management of indigenous medicinal plants in Nigeria using phenological information.
64. Opler P.A., Frankie G.W. & Baker H.G. (1976). Rainfall as a factor in the release, timing and synchronization of anthesis by tropical trees and shrubs. *Journal of Biogeography* 3: 231 - 236.
65. Opler, P.A., Frankie, G.W. and Baker, H.G., 1980. Comparative phenological studies of treelet and shrub species in tropical wet and dry forests in the lowlands of Costa Rica. *The Journal of Ecology,* pp.167-188.

66. Ouédraogo, L., Endl, J., Sombié, P.A.E.D., Schaefer, H. and Kiendrebeogo, M., 2020. Ethnobotanical use and conservation assessment of medicinal plants sold in markets of Burkina Faso. *Ethnobotany Research and Applications*, 20, pp.1-25.
67. Peñuelas, J. and Filella, I., 2001. Responses to a warming world. Science, 294(5543), pp.793-795.
68. Puchalski, T., 1969. Wybrane zagadnienia z hodowli lasu. Wzrost drzew i drzewostanów. Skrypt Wyższej Szkoły Rolniczej w Poznaniu.
69. Root, T.L., Price, J.T., Hall, K.R., Schneider, S.H., Rosenzweig, C. and Pounds, J.A., 2003. Fingerprints of global warming on wild animals and plants. *Nature*, 421(6918):57–60.
70. Ruml, M. and Vulić, T., 2005. Importance of phenological observations and predictions in agriculture. *Journal of Agricultural Sciences (Belgrade)*, 50(2), pp.217-225.
71. Rutherford, M.C., 1975. Aspects of ecosystem function in a woodland savanna in South West Africa (Ph. D. thesis, University of Stellenbosch).
72. Sakai, S., Momose, K., Yumoto, T., Nagamitsu, T., Nagamasu, H., Hamid, A.A. and Nakashizuka, T., 1999. Plant reproductive phenology over four years including an episode of general flowering in a lowland dipterocarp forest, Sarawak, Malaysia. *American journal of botany*, 86(10), pp.1414-1436.
73. Schnelle F. (1955). Plant Phenology; Chapter 1: Tasks and Nature of Phenology (pp. 11-12)
74. Scholes, R.J. and Walker, B.H., 1993. An African savanna: synthesis of the Nylsvley study. Cambridge University Press.
75. Scott, J.D., 1934. Ecology of certain plant communities of the Central Province, Tanganyika Territory. *The Journal of Ecology*, pp.177-229.
76. Scott, P.E. and Martin, R.F., 1984. Avian consumers of Bursera, Ficus, and Ehretia fruit in Yucatan. Biotropica, 16(4), pp.319-323.
77. Shemishere, U.B., Anyebe, D.A., Bashir, A.Y., Emmanuel, J., Ifie, J. and Yahaya, T., 2020. Phytochemical screening and free Radical Scavenging activities of methanol leaf and flower extract of Securidaca longipedunculata. *FUDMA Journal of Sciences* - Vol 4, No. 1, pp.37-42.
78. Sparks, T.H. and Carey, P.D., 1995. The responses of species to climate over two centuries: an analysis of the Marsham phenological record, 1736-1947. *Journal of Ecology*, pp.321-329.
79. Stevenson, P.C., Arnold, S.E. and Belmain, S.R., 2014. Pesticidal plants for stored product pests on small-holder farms in Africa. *In Advances in plant biopesticides* (pp. 149-172).

80. Stevenson, P.C., Dayarathna, T.K., Belmain, S.R. and Veitch, N.C., 2009. Bisdesmosidic saponins from Securidaca longipedunculata Roots: Evaluation of deterrency and toxicity to coleopteran storage pests. Journal of Agricultural Food Chemistry, 57(19), pp.8860-8867.
81. Stucky, B.J., Guralnick, R., Deck, J., Denny, E.G., Bolmgren, K. and Walls, R., 2018. The plant phenology ontology: A new informatics resource for large-scale integration of plant phenology data. *Frontiers in Plant Science*, 9, p.517.
82. Tabuti, J.R., Kukunda, C.B., Kaweesi, D. and Kasilo, O.M., 2012. Herbal medicine use in the districts of Nakapiripirit, Pallisa, Kanungu, and Mukono in Uganda. *Journal of ethnobiology and ethnomedicine*, 8(1), pp.1-15.
83. Jayasekara, T.K., Stevenson, P.C., Hall, D.R. and Belmain, S.R., 2005. Effect of volatile constituents from Securidaca longepedunculata on insect pests of stored grain. *Journal of chemical ecology*, 31(2), pp.303-313.
84. Tiawoun, M.A.P., Tshisikhawe, M.P. and Ligavha-Mbelengwa, M.H., 2017. Seed germination and seedling establishment of *Securidaca logepedunculata* (Polygalaceae).
85. Tilburt, J.C. and Kaptchuk, T.J., 2008. Herbal medicine research and global health: an ethical analysis. *Bulletin of the World Health Organization*, 86, pp.594-599.
86. van Vliet, A.J., de Groot, R.S., Bellens, Y., Braun, P., Bruegger, R., Bruns, E., Clevers, J., Estreguil, C., Flechsig, M., Jeanneret, F. and Maggi, M., 2003. The European phenology network. *International Journal of Biometeorology*, 47(4), pp.202-212.
87. Van Wyk, B.E. and Gericke, N., 2000. People's plants: A guide to useful plants of Southern Africa. Briza publications. pg 268.
88. Van Wyk, B.E., Van Oudtshoorn, B., Gericke, N. (2009). Medicinal plants of South Africa, second ed. Briza Publications, Pretoria. pg 268.
89. Watt J.M and Breyer-Brandwijk M.G. (1962). The Medicinal and Poisonous Plants of Southern and Eastern Africa, 2nd Ed. Livingstone.
90. Whitfield, J., 2001. The budding amateurs. Nature, 414(6864), pp.578-580.
91. Zulu, D., Thokozani, B.L., Sileshi, G.W., Teklehaimanot, Z., Gondwe, D.S., Sarasan, V. and Stevenson, P.C., 2011. Propagation of the African medicinal and pesticidal plant, Securidaca longepedunculata. *African Journal of Biotechnology*, 10(32), pp.5988-5992.

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APPENDIX

Date :	18-Dec-18	DATA COLLECTION WORKSHEET											
Observation No 4		Phenophases of Securidaca longepedunculata											
Group No.:……		1							Season	Mid Summer			
Sheet No.:……		1											
		Put a cross when you observed phenophase(Yes) or Not (No)											
Phenophases		Trees	No.1	No.2	No.3	No.4	No.5	No.6	No.7	No.8	No.9	No.10	Average
		GPS	24,65852	24,65926	24,65877	24,65878	24,66096	24,66186	24,66178	24,66219	24,66219	24,66219	
			28,72199	28,72193	28,72115	28,72087	28,71562	28,71598	28,71630	28,71730	28,71730	28,71730	
		Other											
Vegetative phenophase	Budding	Yes											
		No	x	x	x	x	x	x	x	x	x	x	0%
	Leaf Greening	Yes	x	x	x	x	x	x	x	x	x	x	
		No											
		%	90	90	95	95	100	95	95	70	90	80	90
	Leaf Yellowing	Yes	x	x		x		x		x	x	x	
		No			x		x		x				
		%	5	10	0	5	0	5	0	5	10	10	5
	Leaf Shedding	Yes	x		x				x	x		x	
		No		x		x	x	x			x		
		%	5	0	5	0	0	0	5	25	0	10	5
Reproductive phenophases	Flowering	Yes	x	x	x	x	x	x	x	x	x	x	
		No											Present
	Unripe	Yes	x	x	x	x	x	x	x	x	x	x	
		No											
		%	70	75	75	85	60	75	85	60	80	85	75
	Ripe	Yes	x	x	x	x	x	x	x	x	x	x	
		No											
		%	30	25	25	15	40	25	15	40	20	15	25
	Seed Shedding	Yes											
		No	x	x	x	x	x	x	x	x	x	x	
		%	0	0	0	0	0	0	0	0	0	0	0

Appendix A: Data collection sheet used to capture information on the field for each ten of the 200 *Securidaca longependuculata* plant individuals. An example of data collected during the 4^{th} observation visit in December month(mid-summer) as first marksheet for group 1.