The study of phenophases of *Lantana camara* in some parts of Makhado Municipality; Limpopo Province, South Africa

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DECLARATION

I, Kwinda Aluwani Ndanduleni, hereby declare that the work done on the research titled **"The study of phenophases of *Lantana camara* in some parts of Makhado Municipality; Limpopo Province, South Africa."** that is submitted to the University of Venda for Master of Science Degree in Botany is my original work and have not been submitted to any other university or institution for any degree. Any other research done by any other individual or institution or any material attained from other sources has been cited accordingly and referenced.

15 February 2022

…… ……

Signature Date

DEDICATION

This research is dedicated to my mother, who generally upheld me and appeal to God for my accomplishment in schooling. She believes that “tough times do not last but tough people do”. To my beloved family who show love and support all the time and Hundreds of men and women who are in the community in pursuit of a healthy living.

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At last, I offer my exceptionally significant thanks to Thinavhuyo, Rendani and Azwidohwi Kwinda; my siblings for furnishing me with unfailing help and constant consolation all through my long stretches of study and through the most common way of researching and writing this report. This achievement would not have been imaginable without them. Much thanks to you.

ABSTRACT

A few strategies have been utilized in plant phenology to observe the starting date of the life cycle events and the basic temperature for development and improvement of perennial plants. The study of phenophases on plant species required clear observations, interpretations and the recording of the plant yearly life cycle that can be characterized by the start and the end of each stage. According to the USA National Phenology Network, phenophases generally have a duration of a few days or weeks depending on the type of plant species. This study considered the various phenophase events of *Lantana camara,* an alien invasive shrub which poses a major threat to the biodiversity by suppressing the growth of indigenous species in the ecosystem as observed in some parts of Makhado Municipality. This study aimed to determine when different phenophase events of *L. camara* occurred, compared the duration of lifespans of each reproductive phase and established relationships between different phenophase events of the plant. The study was done by conducting field observations using digital repeat photography method on monthly basis for 12 months in some parts of the Makhado Municipality, Limpopo Province. The study areas were Ha-Mashau, Doli village and Elim. Observations were done randomly once or twice a month to observe as to when the life cycle events of *Lantana camara* begin and end. Findings showed that there was variation amongst phenological events of *Lantana camara* at both the study locations that were visited. *Lantana camara* did not carry leaves, flowers, and fruits for equal periods of times. This variation between phenophases was thought to be caused by environmental factors acting on the plants such as daily temperature, amount of rainfall, and soil moisture content amongst other factors at these locations.

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Chapter 1

BACKGROUND OF THE STUDY AND REVIEWED LITERATURE

1.1 Background of the study

1.1.1 General description of *Lantana camara* and its global invasion

The genus *Lantana* within the Verbena family (Verbenaceae) as described by Linnaeus in 1753 contain seven species, six from South America and one from Ethiopia (Munir, 1996). It is a hybrid shrub complex bred from parents native to tropical and subtropical America (Urban and Besaans, 2011) and only a few taxa are native to tropical Asia and Africa (Munir, 1996). It is one of the most environmentally and economically damaging invasive alien plants in warm temperate regions of Africa, southern Asia, and Australia together with Oceania's tropical and subtropical regions (Day *et al*., 2003).

Day *et al*. (2003) also reported that *Lantana camara* is found infesting various climatic and geographic ranges and mostly in range of ecosystems such as open grazing lands, forest regions, national parks, rainforest edges, riparian areas and along roads and fence lines.

According to report Ghisalberti (2000), the number of *Lantana* species recorded in specific entities ranges from fifty to two hundred and seventy, although it appears that a fairer estimate is about 150 species. Since species are not permanent and hybridization is common, the shape of inflorescence changes with age, and flower colors alter with age and maturity, the *Lantana* genus is difficult to describe taxonomically. (Munir, 1996).

The Agricultural Research Council-Plant Protection Research Institute fact sheets on Invasive Alien Plants and their control in South Africa demonstrate that in the early 1600s, several *Lantana* species from the West Indies, Mexico, and Brazil were brought into Europe as garden ornamentals. (Urban and Besaans, 2011). Plant breeders chose and hybridized them into hundreds of various types, which were subsequently distributed worldwide in arrays of hundreds of identified horticultural hybrids. (Urban and Besaans, 2011).

Lantana camara L. is therefore one of the species that has been linked to a wide range of harmful effects on native plant species around the world. (Day *et al*., 2003). It can outcompete or replace native species due to its ability to grow and spread fast, its unpalatability and its being allelopathic in nature (Anthony, 2008).

Moldenke was the first person to infer *L. camara* potential for hybridization in 1971 (Spies 1984). The same author published evidence of hybridization within the *L. camara* species in the Eastern Transvaal lowveld at White River, Mpumalanga, where a total collapse of isolating mechanisms between distinct forms of *L. camara* resulted in the emergence of a hybrid swarm. Hybridization of this plant leads in a constant fluctuation of features between the parental extremes, and hybrids can sometimes outgrow and outperform their parents (Spies, 1984).

Lantana camara shrub is commonly used to beautify gardens and has expanded throughout the world from its native Central and South America to over fifty nations, including South Africa (Day, 2003). In 1807 *L. camara* was introduced to South of Asia in India as a decorative plant species in the National Botanical Gardens of Calcutta; later broke free and spread over the Indian Subcontinent, and it is now considered one of the ten worst weeds (Balasubramanian, 2017).

1.1.2 *Lantana camara* taxonomy

Scientific name: *Lantana camara*

Common name(s): **Big sage** (Malaysia), **red sage-white sage-wild sage** (Caribbean) and **tickberry** (South Africa).

Table 1.1: *Lantana camara* taxonomy review (Munir, 1996).

Kingdom	Plantae
Division	Magnoliophyta
Class	Magnoliopsida
Order	Lamiales
Family	Verbenaceae
Genus	*Lantana*
Specie	*Camara*

1.1.3 *Lantana camara* in South Africa

According to the Alien and Invasive Species Regulations (AIS), National Environmental Management: Biodiversity Act (Act No. of 2004), land occupiers are legally required to regulate or remove *Lantana camara* where practicable (Urban and Besaans, 2011). Urban and Besaans (2011) claim that *L. camara* arrived in South Africa in 1858, settling in Cape Town, Western Cape Province, where it thrives in the Mediterranean environment. The same author then reported that *L. camara* then flourished under subtropical condition in 1883 in Durban, KwaZulu-Natal Province. It was then labeled a notorious weed in 1946 in KwaZulu-Natal, which at the time

comprised 80% of the South African infestation, and was doubling in size every decade (Urban and Besaans, 2011). *Lantana camara* had infested between 25 000 and 30 000 acres of land in South Africa, according to a 1962 survey (Stirton, 1977; Wells and Stirton, 1988). It is evident that *L. camara* was estimated to have infested a total area of two million hectares in South Africa in the year 2000, with a combined condensed area of over 70 000 ha (Le Maitre *et al.,* 2000). However according to Vardien *et al*. (2012), *L. camara* thickets are obstructing access to water sources. It degrades water quality in rivers and streams, such as in the Western Cape's Hartenbos and Klein Brak River catchments (River Health Programme, 2003). *Lantana camara* is widely distributed throughout the Western Cape, Eastern Cape, KwaZulu-Natal, Mpumalanga, Limpopo, and Northwest provinces, according to the list of invasive species in South Africa (Invasive Species of South Africa, 2019).

1.1.4 Biology

Lantana camara is a thorny multi-stemmed, deciduous shrub with an average height of about two metres and the stems are square in outline, coated with bristly hair while green, and commonly sprinkled with little prickles (Priyanka and Joshi, 2013). The root system of *L. camara* plants is strong, and the leaves are opposite, simple, with long petioles, oval blades that are rough and silky, and have a strong aroma. Leaves are green and change colour towards senescence stage (Priyanka and Joshi, 2013), and florets open yellow or white and turn pink, orange, or red as the flower head matures. (Urban and Besaans, 2011) and they undergo colour change subsequent to anthesis (Priyanka and Joshi, 2013). Clusters of berry-like fruits are green in colour and turn blackish when ripe (Urban and Besaans, 2011). According to Choyal and Sharma (2011) there are allelochemicals present in all the parts of this shrub and when these

chemicals are released in the areas surrounding this shrub, they interfere with germination of many other species.

Table 1.2.: Table showing A-flowers, B-leaves, C-fruits and D-stem of *Lantana camara* species.

			
A	**B**	**C**	**D**

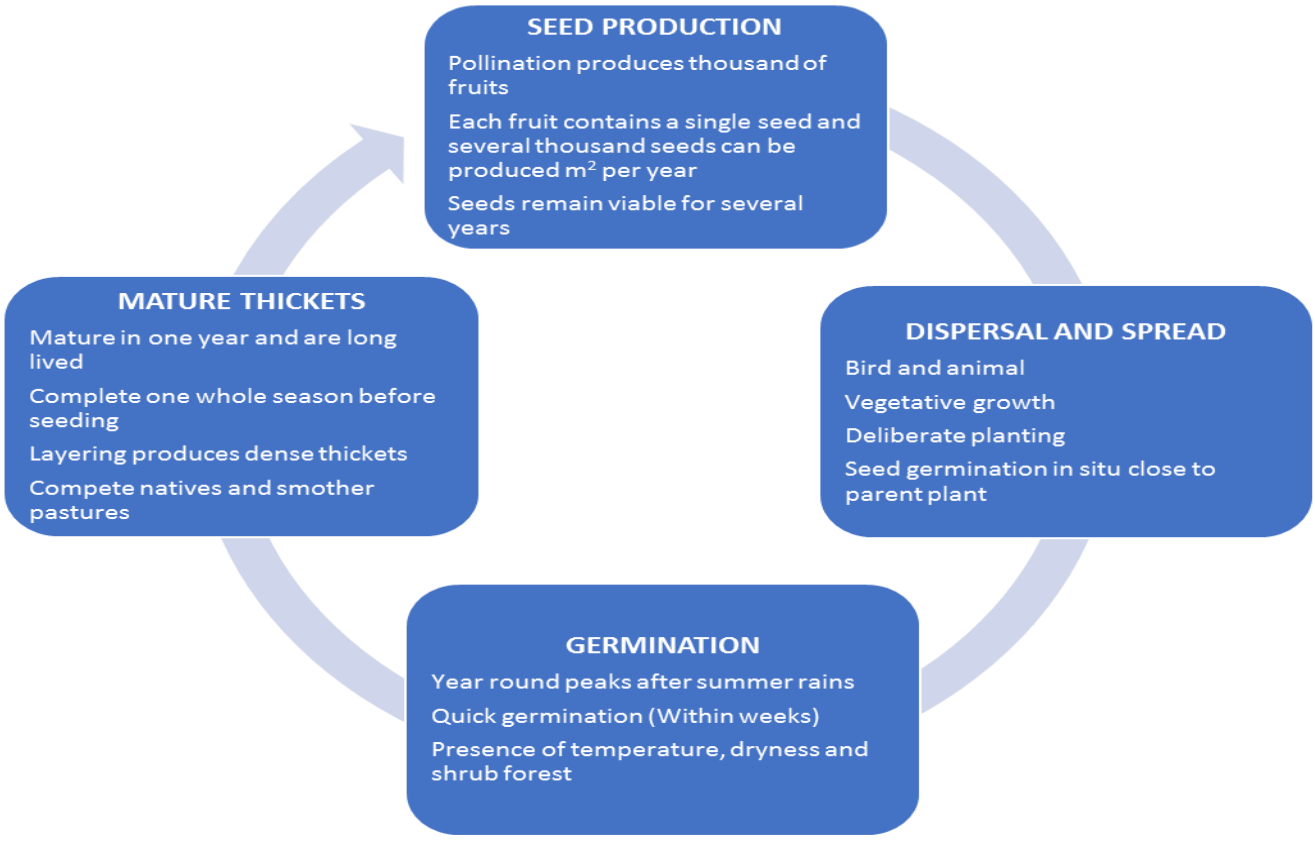


Figure 1.1: Typical life cycle of *Lantana camara* (Priyanka and Joshi, 2013).

1.1.5 Review on phenology of species

Crimmins and Crimmins (2008) conducted a study on tracking plant phenology using digital repeat photography, and they did it by extracting an estimate of greenness and counts of individual flowers from the photo time series using mathematical methods. Meteorological measurements taken at the study site in Tucson, United States of America, were used to interpret the metrics. According to their findings, average greenness increased steadily from the beginning of the study period in June 2006 until about mid-September 2006, corresponding to the germination and growth of various plants in the experimental plots. Greenness reached its first peak in mid-September the same year and extended until the beginning of November. The same authors

reported that at the end of November, there was a reduction in greenness. Finally, from early August to early September, flowering expanded significantly, that is when the flower peak was recorded. There were two flowering peaks, on September 6 and September 25, with a decline in counts in between (Crimmins and Crimmins, 2008). On September 7, following two heavy rains, a significant drop in flower counts was observed using the counting algorithm. After September 25, flower counts produced using the counting algorithm progressively dropped, and most blooms were senescent by mid-October, the same author reported.

Ollerton and Lack (1998) conducted a study on the relationships between flowering phenology, plant size and reproductive success in *Lotus corniculatus* of Fabeceae family for a period of three years.

Figure 1.2: *Lotus comiculatus* known as Bird's foot trefoil (Photo adopted from; botanika.wendys.cz).

The same authors analyzed the flowering phenology of individuals of the above-mentioned *Lotus corniculatus* in connection to fruit set and seed predation during a three-year period to discover the relationship between four components of flowering, plant size, and reproductive performance. The timing of first and peak flowering, as well as flower synchronization, vary amongst individuals in the species, according to the two authors. They also reported that in some years, fruit production and seed predation were linked to specific aspects of blooming phenology, but not in others and they concluded that plant size not only has a direct effect on individual plant fecundity, but it can also influence flowering time and hence indirectly affect reproductive output.

In his study, Schnelle (1955) analyzed the importance of phenological observations and came to the conclusion that these affordable and useful "plant instruments" are essential instruments that respond to a variety of climatic and environmental conditions. Menzel (2002) discussed that plant phenophase events are strongly influenced by meteorological factors. Plant growth necessitates adequate light, water, mineral nutrients, oxygen, and a comfortable temperature, according to the same author. Many environmental and physiological processes are required by these simple demands, including meteorological factors (light, temperature, precipitation, wind, photoperiod, and gases), edaphic factors (topography, slope, exposure, and other soil properties), and biotic factors such as pests, diseases, and competition among species (Menzel, 2002). The reproductive cycles of plants in temperate zones are principally governed by temperature and day duration and Menzel (2002) concluded that temperature mainly regulates the timing of leaf unfolding of trees such that chilling temperature break winter dormancy and subsequent warm temperature induce budburst.

1.2 Statement of the problem

Lantana is a global species that is regarded as one of the worst weeds in the world due to its invasiveness, propensity for spread, and economic and environmental impacts. *Lantana camara is* seen to be spreading widely in many different areas across Makhado Municipality. The infestation of *L. camara* is due to its potential to displace/suppress native species through competition for resources such as water, nutrients and through allelochemicals (Drake *et al*., 2003). These chemicals exert harmful physiological effects on individuals of different species when released into the environment (Cheng and Cheng, 2015) and since allelochemicals are present in all parts of *L. camara*, they interfere with the germination of many other species (Choyal and Sharma, 2011). It is a serious threat to biodiversity, it invades disturbed ground and river margins, expanding its spread in response to rainfall, and poses a hazard to agriculture and pastoral production, forestry, and biodiversity in conservation areas, as well as being toxic to livestock (Parsons and Cuthbertson, 2001).

Figure 1.3: *Lantana camara* infestation at Ha-Mashau Doli Village during first field observation.

Managers are unsure how to use phenophase information to influence their management strategies, despite the fact that climate-induced variations in phenology have been recognized as having a significant impact on resource management (Enquist *et al*., 2013). Changes in plant timing, such as leaf emergence, flowering, and seed distribution, are widely recognised as some of the most vulnerable biological responses to climate change (Cleland *et al*., 2007; Solomon, 2007). According to Walther (2010), phenological changes in plant species have an impact on practically all ecological relationships and processes, including species abundance and distribution. (Miller-Rushing *et al*., 2010).

1.3 Purpose of the study, research questions and objectives

1.3.1 Purpose of the study

To study, analyse and understand the phenophase events of *Lantana camara* in selected locations of Makhado Local Municipality.

1.3.2 Main research question

When do the different phenophases such as budding, leaf emergence, leaf colour changing, leaf shedding, flowering and fruiting occur?

1.3.3 Research objectives

i. To determine the seasons of production of leaves, flowers, fruits, amongst other structures.

ii. To compare the seasons of production of *Lantana camara* in different study areas.

iii. To establish whether there is correlation between flowers and fruits production.

1.4 Significance of the study

To successfully manage invasive alien species, active measures must be made to avoid fresh introductions, attentive detection of burgeoning populations, and ongoing efforts to eradicate these invader species. In this case, the understanding of phenological events of *Lantana camara* species will help with the management and efforts to control its invasion and so bring to light new information because there is little information about reproductive biology of this plant. It will help conservation managers to have an idea as to when should they eradicate or control this plant to reduce its suppression of indigenous plants. Findings of this research will uncover critical information about *Lantana camara* that has not been exposed by other researchers locally.

1.5 Hypothesis

There will be difference between seasons of production of flowers, leaves and fruits amongst other structures between Ha-Mashau Doli village and Elim, this can be due to temperature variations amongst them and edaphic factors of the particular area.

There will be correlation between flower numbers and fruits produced by *Lantana camara.*

1.6 Limitations

This study was limited to two specific locations which are Ha-Mashau Doli village and Elim in the Makhado Local Municipality under the Vhembe district in order to achieve the main objectives of the study. Phenophase observed during the study were strictly limited to the following events; namely are development, foliage (timing of leaf emergence and leaf fall/senescence), inflorescence emergence, flowering, and fruiting phenophase which comprises of fruit development and maturity, senescence, and the beginning of dormancy.

1.7 Structure of dissertation

This dissertation is presented in a single manuscript format which comprises of 5 distinct chapters outlined as follows:

Chapter one introduces the background of the study and reviewed literature on *Lantana camara* together with its phenology and that of other invasive alien species. It also outlines the purpose of the study, main research questions and objectives.

Problem statement, significance of the study, hypothesis and limitation of this research are also outlined.

Chapter two describes the research study area, materials, and method. It presents information about the study location and method followed in phenological observations together with data sampling and analysis.

Chapter three focuses on the presentation and interpretation of results in tables, figures, and pictures.

Chapter four gives discussion of the results obtained and tackles the objectives of the research. Work from other scholars were used to support the findings of the study.

Lastly, chapter five gives a general summary of the research, conclusions, and recommendations.

Chapter 2

STUDY AREA, MATERIALS AND METHODS

2.1 Study area

2.1.1 Location

In the Makhado Local Municipality in the Vhembe District of Limpopo Province, South Africa, a study was conducted in two different places. Makhado Local Municipality is in the northern parts of Limpopo Province (23° 00´ 00´´ S 29° 45´ 00´´ E) approximately 100km from the Zimbabwean border along the N1 Route (http://www.makhado.gov.za/?q=background). The municipal territory is 831 058 hectares in size, with an estimated population of 416 728 persons. The municipality may be described as predominantly rural due to the magnitude of the rural population. (http://www.makhado.gov.za/?q=background). The two locations that the research was carried out are at Ha-Mashau (Doli) Village and Elim.

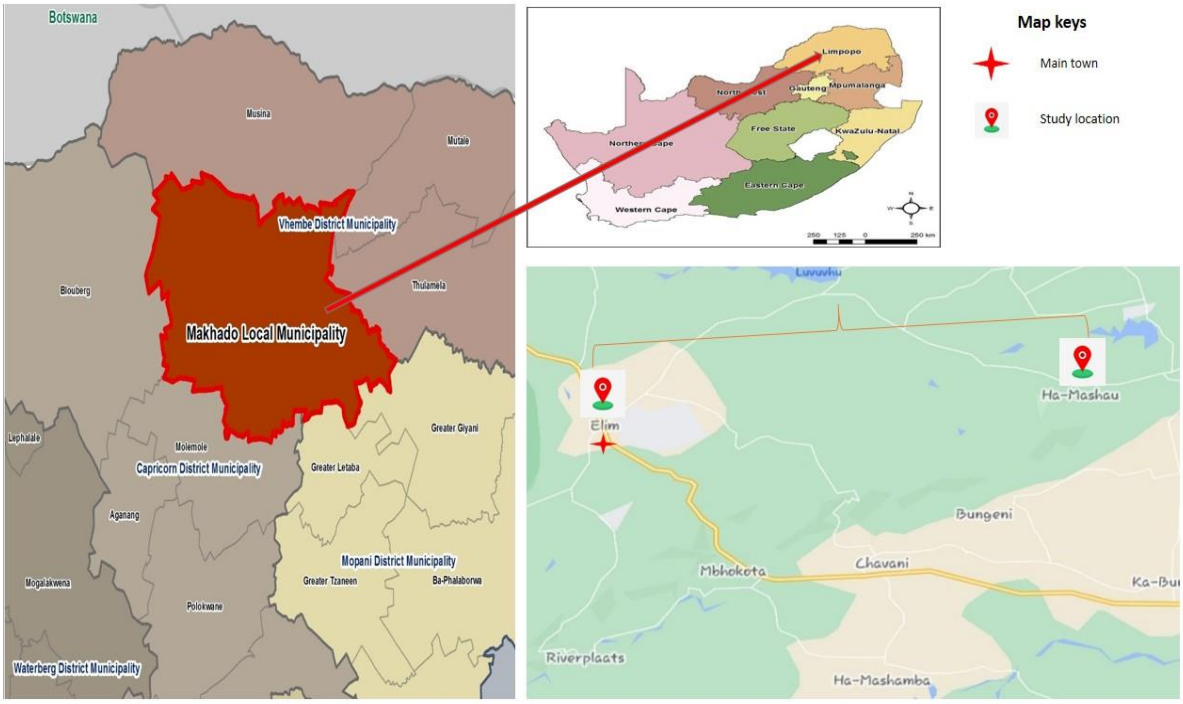


Figure 2.1: Makhado Local Municipality map including study areas.

Ha-Mashau Doli is a locality (class L – Area) with coordinates of 23°7'60" S and 30°18'0" E in Degrees Minutes Seconds. It is located at a height of 693 meters above sea level (http://www.getamap.net/maps/south_africa/limpopo/_hamashau/). Elim is a town outside Louis Trichardt with coordinates of 23°22'60" S and 28°34'60" E. It is located at an elevation of 895 meters above sea level. (http://www.getamap.net/maps/south_africa/limpopo/_elim/).

2.1.2 Geology

The two areas were chosen to conduct this study because it was seen infested with *Lantana camara* species of different variety. According to Bumby (2000) the geology of rocks of the Sibasa formation of the Soutpansberg group consists of basalts with intercalated elastic sediments, dominates Ha-Mashau Doli hamlet. Soils in this area

were derived from basalts and sandstones, with sandy, loamy, clayey soils, and shallow silt sand found in river valleys as general soil types. (Mostert *et al*., 2008). The major rock formation of the mountain around Elim is made up of sandstone, quartz sandstone, and quartzite, as well as a few volcanic intrusions primarily composed of basalt and dolerite. As a result, the sandy soils of the Elim area are made up of weathered sandstone and quartzite (Mostert *et al*., 2008).

2.1.3 Climate

Makhado Local Municipality is situated in the lowveld, with a savanna as well as areas with considerable rainfall. Makhado has a moderate and temperate climate, with substantially less rainfall in the winter than in the summer (www.en.climate-data.org>africa). The annual temperature is 18.7 degrees Celsius (°C), with 793 millimetres of rainfall (www.en.climate-data.org>africa). Louis Trichardt's average noon temperatures range from 20.2°C in June to 27.1°C in January (www.seaexplorer.co.za). The region is the coldest during July when the mercury drops to 5.5°C on average during the night (www.seaexplorer.co.za). Most of the area's rainfall occurs in the summer months, from November to March. The Municipality has imposed certain water restrictions in recent years, primarily due to drought in the area and the Municipality's failure to maintain the town's water delivery infrastructure.

2.1.4 Habitat

Lantana camara's extensive geographical spread reflects its wide ecological tolerances; it grows in a number of environments and on a variety of soil types. (Balasubramanian, 2017). *Lantana camara* thrives at open edges, canopy-free patches, beachfronts, riparian zones, and woods that have been disturbed by fire or

logging (Thakur *et al*., 1992) and it is also seen sprouting along disturbed areas like railway tracks, as well as roads and canals (Day *et al*., 2003). Urban *et al*. (2011) mentioned that *Lantana camara* can also benefit from destructive foraging activities of introduced livestock and erupted site by a volcano and can also grow at altitude from sea level to 2000 metres. This is due to its potential to grow and survive in a variety of climatic conditions, as well as its tolerance of some shade, allowing it to establish itself in plantations and open forest (Urban and Besaans, 2011).

2.2 Methodology

2.2.1 Phenology observations

According to Vierling *et al*. (1996) when researching phenology events of plant species, remote sensing using satellite and aerial images has been a prominent technique for the past three decades. With its great temporal resolution, digital repeat photography has proven to be effective in monitoring and determining leaf emergence, senescence, and dormancy in tree species (Ahrends *et al*., 2009). Photography research approach enables the researcher to gain a deeper grasp of a complicated and lengthy activity chain, as well as the natural flow of events, and to generate more information and discussion (Buchanan, 2001). In its most basic form, repeat photography can be effective in capturing traditional phenological event information, such as the first date of flowering, date of peak flowering, and senescence (Crimmins and Crimmins, 2008).

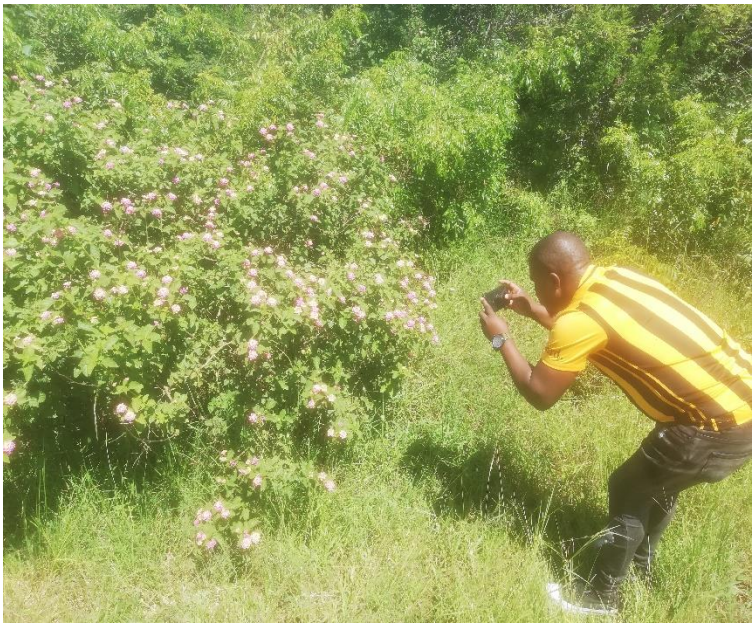


Figure 2.2: Image showing how photography research method was conducted in the field.

To meet the goals of this study, two different study sites/areas which were chosen were Ha-Mashau Doli village and Elim farms, for a period of 12 months to observe the whole phenophase cycle of *Lantana camara* in the same chosen plots of the selected areas. The reason for working in the same plots of the chosen areas is to avoid biasness in the results that will be obtained and discussed after conducting the research. Phenophase events were observed monthly from January to December 2020. Phenophase observations were for the following events:

(1) bud development,

(2) foliage (timing of leaf emergence and leaf fall/senescence),

(3) inflorescence emergence,

(4) flowering, and

(5) Fruiting phenophase which comprises of fruit development, fruit maturation and senescence and the start of dormancy.

It is important to know and understand that all these events will not be seen/take place at the same time; for instance, fruiting must wait upon flowering; seed dispersal cannot precede fruiting (Fenner, 1998). The same author assumed that all events are as a result of natural selection acting on an individual plant whose phenology differs between species.

2.2.2 Data sampling and analysis

During field observations, data was collected using photography research method, in which pictures were taken using a digital camera for every site visit. Every month during visitation to the areas of the study the same methodology of data collection was employed, and the same plots were monitored.

Chapter 3

RESULTS

3.1 Table showing time and duration (seasons) of production of leaves, flowers, fruits and other structures.

Data sheet 1: Principal growth stages (phenophase events) of *Lantana camara* and the time of the year they occur at Ha-Mashau Doli Village and Elim.

Keys: Peak of growth event: ✦

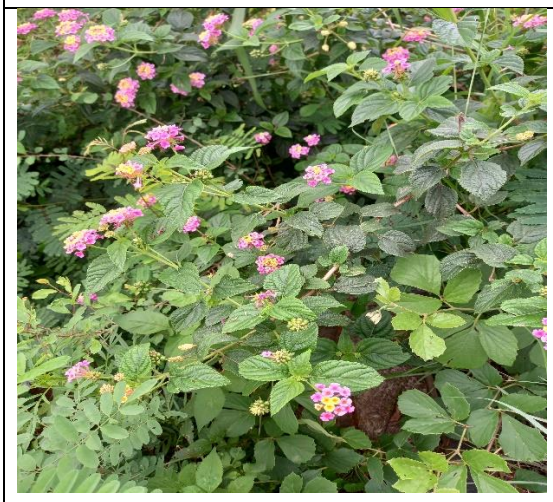
Location	Phenophase	Month of occurrence (Jan – Dec 2020)											
		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Ha-Mashau Doli Village	Sprouting/bud development											✦	
	Leaf greening	✦											
	Flowering phase			✦									
	Fruiting phase (unripe)			✦									
	Repining/fruit maturity				✦								
	Leaf yellowing phase								✦				
	Leaf shedding									✦			
	Senescence beginning of dormancy									✦			

Location	Phenophase	Month of occurrence (Jan – Dec 2020)											
		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Elim	Sprouting/bud development											✦	
	Leaf greening	✦											
	Flowering phase		✦										
	Fruiting phase (unripe)			✦									
	Repining/fruit maturity			✦									
	Leaf yellowing phase								✦				
	Leaf shedding									✦			

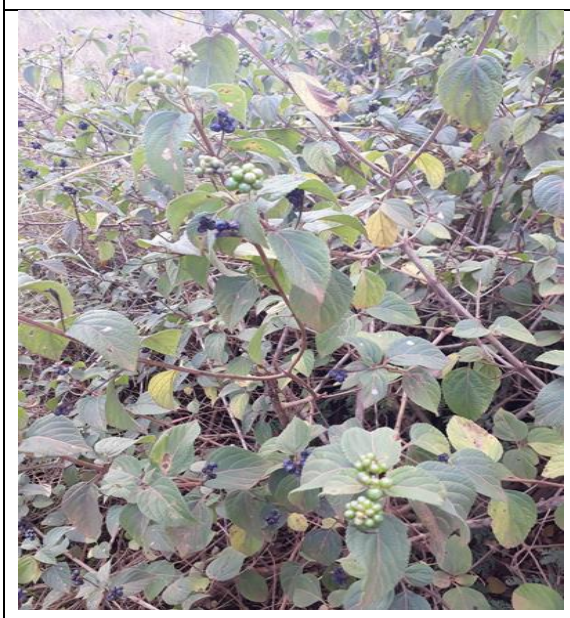
	Senescence beginning of dormancy												

Data sheet 2: Tables below show four climatic seasons (summer, autumn, winter and spring) as recognized in South Africa together with description of phenophases that take place at a particular location and the time.

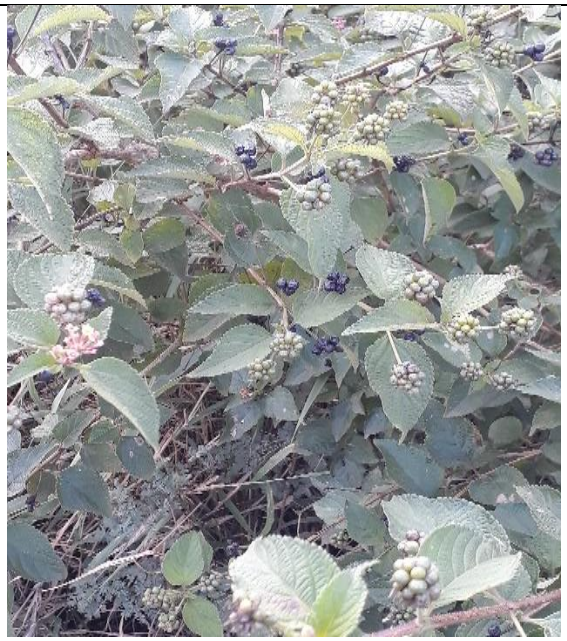
Season of the year	Location	Photograph of phenophase events	Description of the event.
Summer December – February	Ha-Mashau Doli Village	  	In tropic climates *Lantanas* can bloom for nearly throughout the year. In summer months in Ha-Mashau Doli Village, *Lantana camara* was seen with blown leaves and flower together with fully developed fruits which are unripe (green) which covers the whole plant (December). This is due to the fact that flowering and fruiting occur

			throughout the year, with a peak in the first two months of the rainy season. These fruits begun to mature end of January while approaching autumn season.
	Elim		In summer, observations show that *Lantana camara* had developed matured leaves, and significant increase in number of full-blown flowers and the plant had relative number of unripe and significant number of ripe fruits towards
			

			the end of summer season.

Season of the year	Location	Photograph of phenophase events	Description of the event.
Autumn March – May	Ha-Mashau Doli Village	  	*Lantana camara* in the beginning of autumn (March) was seen to be already full green with significant fully-fledged flowers of pink and yellow colour. There were also numerous numbers of green fruits and purple-black fleshy fruits showing in mid-summer with flower number declining and prevalent green and ripe fruits whilst some ripe fruits were at shrinking stage in late summer. In late

			summer (end May) there were numerous green leaves and few starting to yellow, flowers had already been shed. It was found that the plant had dark green leaves which was caused by dust (limiting factor) from the gravel road along the study area.
	Elim		In early autumn month of March, Elim had full blown bright green leaves with significant number of fully-fledged flowers of pink and yellow colours. There were also numerous
			

			numbers of green fruits and purple-black fleshy fruits showing. Only few to no flowers were seen together with a majority of ripe fruits that some had begun to shrink in late summer as a result of winter season approaching.

Season of the year	Location	Photograph of phenophase events	Description of the event.
Winter June – August	Ha-Mashau Doli Village	  	In the beginning of winter season (June), these plants were having yellowish leaves prevailing with green leaves declining in number. Flowers were completely shed whilst very few green fruits were still showing, and ripe shrinking fruits were seen but not significant in number. In mid-winter all the yellowish leaves had been shed and this was triggered by wind and

			thunderstorms along the season. In late winter, *Lantana camara* were seen almost leafless.
	Elim		Winter season at Elim show plants with fully developed green and yellow leaves, with green leaves covering about 70% of the whole plant. Flowers were sun-scorched and hence shrinking. Both green and ripe fruits were observed with very few ripe fruits already shrunk. Towards end of winter season,
			
			

			plants had shed a significant number of leaves and very few shrinking ripe fruits were seen.

Season of the year	Location	Photograph of phenophase events	Description of the event.
Spring September – November	Ha-Mashau Doli Village	  	In the beginning of spring, plants were observed having few leaves that were at senescing stage, no flowers, and fruits at this time of the year. Most part of the plant was leafless. In October early budding phase had begun with *Lantana camara* having regrown leaves that were bright green in colour and in mid-November the plant had developed significant number of flowers and unripe fruits that had dominated some portions of the plant.

	Elim	  	When temperature normally warms up in the spring, and trees begin to sprout leaves and flowers.. It was observed that the leaves were all shed at Elim location with no flowers seen on the plant and few fruits that were on the plants had ripen but already shrunk in mid-September. In October fully developed leaves were observed with few buds of flowers seen emerging in early November and these flowers were also observed prevailing towards the end of November.

Chapter 4

DISCUSSIONS

4.1 Comparison of season of production of *Lantana camara* in different study areas

Chmielewski and Rötzer (2002) indicated that in middle latitudes, with vegetation rest period in the winter and dynamic developing period in the spring and late spring towards summertime, phenology dynamics of plants is mainly determined by temperature among different variables. It was found that there is variation amongst phenological events between these plants at the study two locations that were visited during the research period. This variation can be caused by environmental factors such as edaphic factors (soil fertility, rainfall amount, soil moisture content and daily temperature variation at these different locations. These factors could affect bud development, leaf shedding, fruiting, and flowering amongst other phenophases.

It is also evident that phenophase events such as formation of buds, flowering, fruiting, dormancy etc. are impacted by a complex blend of environment and non-environment factors, although it is found that temperature is regarded the most important factor that influences plant phenological events (Mostert *et. al*, 2008). Frost and precipitation are weather events that can also influence many species phenophase and it is also found that non-climatic factors, for example, photoperiod and site-specific habitat characteristics such as soil type being sandy soil, loamy soil, clay soil, shallow silt sand and the slope of an area can also have an important effect on phenology (Mostert *et. al*, 2008).

As compared to other research done, leaf detachment of species of family Bombacaceae react to a general proximate environmental signal associated with the

dry season, the date and time of flowering and fruiting of each species was comparative between locations with various dry season intensity and lifespan demonstrating that decent precipitation levels didn't set off blooming in these species and finally similar species bloomed at comparable times in Costa Rica and Mexico. (Lobo *et al.*, 2013).

Observations carried out in this research show results that seasonal peaks of different phenophases were seen in the mid-month of a particular season in each location. *Lantana camara* species of Elim location begun bud development phase early November of southern Africa spring season and has showed slight difference to those of Ha-Mashau Doli village which was observed in mid-October. This was because observation showed that in late winter season (August end) of Ha-Mashau Doli village, these plants were seen with very few leaves showing. So, the budding process begun earlier than Elim location which begun few weeks after budding phase of Ha-Mashau Doli. These slight difference between the two study locations can be because of the soil type and temperature variations between the two locations amongst other factors. To explain this further, Ha-Mashau Doli village soil is red loamy that is mixed with a bit of sandy soil that is found to be rich in nutrients. Elim has semi loamy soil mixed with sandy soil that is found to be a limiting factor.

Balasubramanian (2017) conducted a study on fruiting phenology in India and results showed that *Lantana cama*ra bore fruits from May to September and the fruiting peak was seen in July; this is different to this study because observed results show that *Lantana camara* bore fruits from October to March and fruiting peak was recorded in March (Autumn season) in both the location but the difference were only between weeks as Ha-Mashau Doli village peak was early March and Elim late March. This can be a result of the Makhado area having high rainfall in summer than in winter. Priyanka

and Joshi (2013) estimated that an individual plant of *L. camara* produces about twelve-thousand fruits every year while germination process starts when a bird, a mammal or insects such as bees, moths and butterflies which are common pollinators had fed on the fruits and the seed has travelled to the gut.

Fruits of *Lantana camara* were available throughout the course of this study in all locations except in end August (winter) and beginning of September (spring) where fruits were no longer available at Ha-Mashau Doli. These species might have lost their fruits due to certain conditions such as wind breaks that blew away the fruits in the plants or by a long period of dry season resulting in the plants suffering from insufficient amount of soil moisture and therefore the plant fail to produce or keep fruits for a longer duration. Certain fruit plants require sunlight to grow and reproduce. For example, *L. camara* was observed in a plot exposed to sunlight (Figure 4.1) and found growing well under shade (Figure 4.2).

Figure 4.1: *Lantana camara* exposed to sunlight during spring season.

Figure 4.2: *Lantana camara* flourishing under shade.

Lantana camara is mostly found growing/occupying land where it is exposed to sunlight, and it was found flourishing in areas with high temperatures (e.g. Elim as *L. camara* has been flourishing under high temperatures because it is found exposed to direct sunlight). Although the climate conditions around Makhado Local Municipality is the same, the difference between the times of phenophases in these study locations can be due temperature changes that is affecting a particular area on a day-to-day basis.

Balasubramanian (2017) reported that fruits of *Lantana camara* were available throughout the year in Hong Kong; Southern China (Corlett, 2005) and other parts of South Africa (Graaff, 1987). Findings in these studies therefore show similar differences with what was found by the current study because in both locations fruits were observed throughout the year except in a short period were these plants had completely lost their fruits, late winter in August at Ha-Mashau Doli (Figure 4.3) and early spring September at Elim (Figure 4.4) and this might be an indication that

phenophases times of some similar alien invasive species are dictated upon by the prevailing immediate environmental factors of any area.

Figure 4.3: Late winter in August at Ha-Mashau Doli village with *Lantana camara* observed completely lost their fruits.

Figure 4.4: Early spring September at Elim with *Lantana camara* observed completely lost their fruits.

These similar responses of *Lantana camara* of different countries might be reflection of the generalist strategy of life that is adopted by alien invaders. Weather and climate of Makhado Local Municipality areas differ from those in Hong Kong, South China. *Lantana camara* in Ha-Mashau Doli and Elim did not carry leaves, flowers and fruits for equal periods of times. This might be the implications of microhabitat heterogeneity or differences in some environmental factors such as temperature, soil type amongst other factors.

The difference in the times of the *Lantana camara* plants to lose their flowers in both the study locations (Ha-Mashau Doli and Elim) can be due to temperature fluctuations that greatly affect plant blooms. Soil fertility can inhibit the continuance of healthy blooming of flowers, direct exposure to sunlight and wind breaks are important factors amongst others that lead to flower loss of the plant (Menzel, 2002). Pests that get inside the buds and feed on the petals can also damage the flower (https://www.gardeningknowhow.com).

Lieberman (1982) reported that in Ghana, flowering together with fruiting, leaf production and leaf fall change all show a strong seasonal pattern in grassland and tropical forest ecosystems and moisture shortage limit phenophase events activity in spite of the fact that patterns vary amongst species. In dry tropical forest of Ghana, flowering and fruiting occur throughout the year and the same patterns for fruiting and flowering are observed for species grouped according to habitat and life-form (Lieberman, 1982).

Plants can respond to the change of season by losing their leaves, fruits, flowers or by breaking dormancy. Leaf shedding can be due to changes in the length of day light and changes in temperature. Since alien invaders are known to use the generalist

strategy that enable them to strive in a wide variety of environmental conditions and can also utilize a wide range resources; it can be assumed that *Lantana camara* take advantage of dry season or very harsh climate conditions by losing leaves completely to reduce water loss through evapotranspiration. The previous mentioned strategy was seen in Elim during the month of September where the plant was seen completely leafless with only few shrunk fruits remaining (Figure 4.6).

Figure 4.5: *Lantana camara* with all leaves completely shed.

4.2 Correlation between flowers and fruits production

According to Morgan (1993) many more flowers than fruits are produced by hermaphroditic flowering plants. In his observations he interpreted that in view of the trade-off occurring between the size and flower numbers that mature when resources are restricting. At the time of flowering, his model included resource allocations to male and female reproductive structures, as well as fruit maturation. As a result, his model demonstrated that less fruits were matured than the flowers that were produced by the plants, even without a trace of elements like pollinator limitation and bet-hedging

notwithstanding environmental variability. Findings are the same as for *Lantana camara* plant species that were observed in this research as recorded from Ha-Mashau Doli village and Elim study location. Morgan (1993) model results also emphasized the contributions to male and female success differ depending on whether the flower or the inflorescence is present. His analysis also elaborated that fruit to flower ratio in hermaphroditic plants was lower than that in female plants, in accord with broad taxonomic surveys.

This study shows that there is no correlation between flowers and fruits of *Lantana camara.* Results show that number of flowers that *Lantana camara* produce during flowering phase at both the study locations were higher than the ovary of the flower that developed into the fruit (Primack, 1987). As a general rule, pollen donation and receipt in an individual flower structures should procedure an integrated structure that must be effective (Primack, 1987).

A common understanding between a flower and fruit relationship is that the more flowers that get fertilized the more the plant can yield, giving the species longevity. Observation from Ha-Mashau Doli village and Elim show that fewer fruits numbers might have been a triggered by flower abortion that took place before the ovary of the flower develop to mature fruits (Figure 4.6). This might have been caused by environmental factors such as windbreaks which are common around the area, plant exposure to harsh conditions e.g. High temperature as well as an array of animals and insects that can damage the flower amongst other factors. Flowering is influenced by a variety of elements, including light moisture, nutrient content, and genetic composition of plant species. These parameters vary by plant species, and the actual mechanism behind the transformation is not fully understood.

Figure 2.6: Flower abortion due to harsh conditions and windbreak.

Chapter 5

SUMMARY, CONCLUSION AND RECOMMANDATIONS

5.1 Summary

Researches on plant phenophase events has acquired expanding consideration as a result of the awareness of phenology to environmental change and its consequences for biological system function. Ongoing mechanical improvement has made it conceivable to accumulate significant information at an assortment of spatial and environmental scales. In spite of our ability to notice phenological change at different scales, the mechanistic basis of phenology is still not well understood. Studying plant phenological events has proved to be important during environment management since there are invasive alien species that are suppressing native/indigenous vegetation.

The utilization of digital repeat photography strategy as an essential method for recording on field site observation has proved to be efficient and easy to execute. While photos and spectral data are vital to phenological research, acquiring better understanding of the physiological mechanisms overseeing phenology is essential (Tang *et al*., 2006). Changes in plant phenology have critical results on biological system efficiency, carbon cycling, competition, food networks, and other environment functions and services.

5.2 Conclusion

Findings from our study showed that there is variation amongst phenological events of *Lantana camara* at both study locations that were visited. *Lantana camara* did not

carry leaves, flowers, and fruits for equal periods of times. This variation between phenophases was thought to be caused by environmental factors acting on the plants such as daily temperature, amount of rainfall, and soil moisture content amongst other factors at these locations. Phenology is maybe the least complex way by which to follow changes in the behaviour of species. However, plants can be used as integral biological indicators for changing environmental conditions (Menzel, 2002).

The great advantage of plant phenophase observations is that they are very reasonable to illustrate and communicate environmental change impacts. From the current literature on phenological events in plant communities it can be concluded that there is a need to conduct further research in order to understand the different phenological events of plant communities, utilizing more reliable phenological information and models created for bigger topographical regions than for a single specific area, in order to advance the understanding of correlation between reproductive structures of different plant species and the interaction between climate and natural systems.

Since *Lantana camara* is a NEMBA: Category 1B, and therefore environmental managers are required to control and eradicate it. It is found that *Lantana camara* has fundamental effects on economic and environmental areas, and it is therefore very challenging to control as seen with infestation at Ha-Mashau Doli village and Elim area. Constant vigilance and the repeated control of new regrowth is critical to success to good management and controlling of its infestation. The study of phenophase events of plant species helps on when to control infestation of such species. The control of new invasions should be really important in light of the fact that the species can extend its reach during great seasons however during poor conditions these plants do not die out.

According to Anthony (2008) phenology ought not to be just considered as "noise" in the current conspecific variability but rather the beginning stage of evolutionary selection within subpopulations. How we might interpret individual species phenological strategies in response to a changing climate stays deficient and subsequently restricts our capacity to develop robust phenology models at the biological system scale (Anthony, 2008). He concluded that with these progressions, phenology models would be better defined and addressed within earth framework models.

5.3 Recommendations

It is recommended that to record all phenological events of *Lantana camara* or any other species, one needs to have enough time to follow through when all these events unfold. This will help to record every timing of the beginning and offset of the vegetation.

According to Tang *et al.* (2006), given the chance of gathering uncommon phenology data with cutting edge innovations, a breakthrough is predicted in process-based phenology modelling, once natural drivers, dose response functions, or sift old capacities are accessible, rather than building solely upon correlative insights in light of past perceptions. They also elaborated that phenology models should represent the rate of micro-evolutionary developmental changes of genotypic phenology controls (Tang *et al.*, 2006).

It is recommended that community must be educated on how and when to control the infestation of *Lantana camara*. However, completely compelling control techniques are not currently available for this ever growing weed to date (Day et al., 2003). It is also

found that in numerous areas, the size of the infestations along with low land values make customary control not possible. However, strategies such as mechanical clearing and hand pulling are appropriate for small patches while controlling these weed and fire can also be utilized over large infested areas (Day *et. al*., 2003). It is also found that there are several chemicals which are effective when applied to regrowth following other treatment when controlling *Lantana camara*.

For one to conduct successful research one needs to overcome all the challenges that a researcher comes across. In this study the biggest challenge was the outbreak of Coronavirus (Covid-19) which led to restrictions that made it difficult to go to the field to collect data as scheduled.

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