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Assessment of plant biodiversity on and off mature stands of *Androstachys johnsonii* Prain and *Colophospermum mopane* (J.Kirk ex Benth.) J. Leonard

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The species that were growing on the stands of *C. mopane* and on open space stands weighed more than those on the stands of *A. johnsonii* in both loam and sandy soil areas. This is probably an indication that there are some toxic chemicals that are excreted from various parts of *A. johnsonii* that caused the suffering and hence lesser weights of the understory species of *A. johnsonii*. The conditions were found to be unfavorable for the majority of the understory species to grow and flourish well under the canopies of *A. johnsonii*. This therefore, might imply that even though *A. johnsonii* possess allelochemical materials, some understory species may adapt to such conditions in the proximity of its vicinity. The decomposition of different parts of the plant on the ground surface under *A. johnsonii* canopies probably results in relatively highest concentration of allelochemical materials in the soil on *A. johnsonii* stands. Limiting factors like shading, temperature, water availability, and soil type may not necessarily be causes of the observed differences as the investigation was carried out from the same areas. The present investigation revealed that *A. johnsonii* in woodlands chokes its understory plants and such plants might eventually die out.

Key words: Allelochemical materials, *Androstachys johnsonii, Colophospermum mopane,* biodiversity, impact.

INTRODUCTION

Plant species grow in very complex situation wherein each one is in demand of space, nutrients, water as well as other resources needed for their survival. In this regard, plants begin to compete with each other due to short supply of resources. Plants then realize the danger of being outcompeted, as such, they develop some defensive mechanisms like emergence of superficial lateral roots which draw water before penetrating into the deeper horizons of the soil and dense canopies which will shade their understory species; ultimately such understories get outcompeted. The introduction of certain species in the area sometimes may result in the reduction of species that originate there. For example, an annual grass called cheatgrass (*Agropyron spicatum*) from

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Europe was accidentally introduced to the area. From the time of its introduction to the present, ranchers have noticed an enormous increase in the abundance of cheat grass and an equally notable decrease in the abundance of blue bunch wheatgrass (Mack, 1981). What caused the shift? Mack (1981) pointed out that the presence of cheat grass greatly reduced the growth and survival of blue bunch wheatgrass.

In other systems, plants interact with others mutualistically, commensualistically and amensualistically instead of competing with them. Amensualism is an interaction that depresses one organism while the other remains stable. One example of amensualism is allelochemical interaction, which involves the inhibition of one organism by another through a release of metabolic by-products into the environment. The by-products which are normally secondary metabolites are selectively toxic affecting some species but not others. One of the most famous examples of allelopathic plants is Black Walnut (*Juglans nigra*). The chemical responsible for the toxicity in Black Walnut is jug lone and is a respiratory inhibitor. Solanaceous plants such as tomato, pepper and eggplant are especially susceptible to jug lone (http: //ceirp.cornell.edu/projects/AR/Allelopathy.html.). These plants, when exposed to the allelotoxin, exhibit symptoms such as wilting, chlorosis and eventually death. Plants that have been observed to be tolerant to jug lone include lima bean, beets, carrot, corn, cherry, catalpa, violets and many others (http://ceirp.cornell.edu/projects/AR/Allelopathy.html.).

Allelochemical materials are viewed by some biologists as simply the mechanism for an aggressive form of competition. Mutualism is a mutually beneficial relationship between two or more organisms, especially one in which neither organism can survive without another. Common examples of mutualism are lichens (algae + fungi), mycorrhizae (fungi + higher plants), symbiotic nitrogen-fixation (bacteria or blue-green algae + higher plants), pollination (insects, birds or mammals + flowering plants), zoochory (animal dispersal of plant propagules), and myrmecophytes (ants + woody plants). Commensualism is a relationship between two organisms in which one lives on or in another organism that is not harmed (or benefitted) by its presence. Commensualism includes epiphytic orchids or bromeliads living on the branches of host trees.

To a large degree, decomposers in the soil and litter beneath communities are affected by the species shedding the litter and penetrating the soil with the roots. For example, soils beneath northern conifer forests are largely acidic, because conifer litter is acidic and its decomposition influences soil pH (Maguire and Forman, 1983). Although forest understory herbs are notably patchy, and over story tree seedlings may be positively or negatively associated with the herbs (Maguire and Forman, 1983), it is likely that amensualism is usually involved. Instead, herb pattern is often determined by the physical quantity and quality of litter, by uneven distribution of soil nutrients, and by micro environmental patterns of soil drainage (Rogers, 1985). Cater and Chapin (2000) studied the effects of competition and microenvironment on boreal tree seedlings. Allelopathy and allelochemicals in rice weed management have extensively been studied (Asaduzzaman et al., 2010).

Plant biodiversity will be less on *A. johnsonii* stands than on the stands of *C. mopane* and on open space stands, whilst plant biodiversity on *C. mopane* stands will be less than on open space stands. *Androstachys johnsonii* is known to be allelopathic to plant species that grow under it whilst *C. mopane* has not been proven as such. Open space stands or stands without huge canopies are generally also not known to be allelopathic. Accordingly it should not be uncommon to observe plant biodiversity more on open space stands than on *A. johnsonii* stands which are both allelopathic and canopied. It should also not be puzzling to further on find more plant species on open space stands than on *C. mopane* stands because of shading from *C. mopane* canopies. What could be the long-term impact of *A. johnsonii* and *C. mopane* on both species diversity and abundance in woodlands and hence in the broader management of these ecosystems?

The aim of this current study is to assess plant biodiversity on and off *A. johnsonii* and *C. mopane* stands. The presence of one species may limit the distribution of others through competitive interaction, such as allelopathy. Allelopathy is a type of competition that occurs between any two or more species that use the same types of resources and live in the same place. For instance, solanaceous plants, such as tomato, pepper, and eggplant are especially susceptible to juglone (a toxic chemical released by walnut tree) (Coder 1999). The objective of this study is to acquire more knowledge on woodland dynamics and hence add such knowledge to the already existing know-hows in the management of woodlands where *A. johnsonii* and *C. mopane* prevail.

The study was conducted at Makuya Nature Reserve in the far northeastern part of the Limpopo Province, South Africa. Makuya Nature Reserve is about 104 kilometers from Thohoyandou town; Thohoyandou town is the former capital city of the former Venda homeland. The study area lies between 30° 50′E and 31° 05′E and 22° 25′S and 22° 35′S. The soil type of the study area varies from loamy sand to clayey in the undulating granitic landscape of the northern Kruger National Park. Annual summer rainfall is from 250 to over 500 mm.

The vegetation is classified as Mopane Bushveld (Low and Rebelo, 1996), and is characterized by a fairly dense growth of Mopane (*Colophospermum mopane*) and mixtures of *Combretum apiculutum*, associated with *Acacia nigrescens*, *Adansonia digitata*, *Commiphora spp*, *and Terminalia pruniodes* and on rocky outcrops, *Androstachys johnsonii*. The sandy-loam soils, low

Figure 1. A photograph illustrating a 4 m × 10 m quadrat under the canopies of *Androstachys johnsonii* (*A. johnsonii*) plants that were growing on loam soil area at Makuya Nature Reserve.

Figure 2. A photograph showing a 4 m x 10 m quadrat under the canopies of *Colophospermum mopane* (*C. mopane*) plants that were growing on loam soil area at Makuya Nature Reserve.

rainfall, high temperatures and lack of frost influence the distribution of this vegetation type (Low and Rebelo, 1996).

MATERIALS AND METHODS

4 m x 10 m quadrats were constructed using a 50 m measuring tape. The figures referred to here are representative samples of how the forty quadrats were constructed and sampled. The plant species that were found in each quadrat were counted and then collected. All collected plant species were put in separate envelopes for biomass determination in one of the biology laboratories of the University of Venda. In the process of collection secateurs were used to cut the plants that could not be uprooted. A digital camera was used to take the photographs of sites in the reserve where quadrats were constructed (Figures 1 to 6).

After measuring their fresh weights/biomasses, the species were then oven dried at 60°C for 48 h. The dry weights were then measured through the use of mettler balances after the 48 h drying period. The dried materials were again put back into the oven to re-dry them until constant weights were achieved. Such constant weights were the ones considered for final recordings.

RESULTS

Generally there were very few or no plant species seen growing in the stands of *A. johnsonii*. In cases were species occurred, they were found not surviving well as compared to the plant species that grew in both *C. mopane* and open space stands on both loam and sandy soil areas. Species biomass and number of species that were understories in the stands of *A. johnsonii* were less as contrasted to those that were understories in both *C. mopane* and open space stands on both loam and sandy soil areas (Figures 1, 4 and 2, 5).

Both the biomass and number of species of almost all the individual species that were growing on all the three categories of stands, that is, *A. johnsonii*, *C. mopane* and open space stands on both loam and sandy soils were found to differ significantly (Table 1a); the biomass and numbers of species that were understories of *A. johnsonii* were less than the understories of *C. mopane* and the species that were growing on open space stands (Figures 1, 4 and 2, 5). It is only between *A. johnsonii* versus *C. mopane* stands on loam soil areas where no significant difference between the numbers of species was found (Table 1a). Significant difference was also found between the biomass and numbers of the species that were growing on *C. mopane* stands and on open space stands (Table 1a); the species biomass and numbers of the species that were growing on open space

Figure 3. A photograph showing a 4 m x 10 m quadrat on a loam soil area without overstory plants (open space stand) growing thereon at Makuya Nature Reserve.

Figure 4. A photograph illustrating a 4 m x 10 m quadrat under the canopies of *A. johnsonii* plants that were growing on sandy soil area at Makuya Nature Reserve.

Figure 5. A photograph showing a 4 m × 10 m quadrat under the canopies of *C. mopane* plants that were growing on sandy soil area at Makuya Nature Reserve.

stands were greater than those of the species that were growing on *C. mopane* stands (Figures 1, 4 and 2, 5).

Generally the number of individuals of the different species that were found occurring on both loam and sandy soil areas were found to differ (Table 1b); with the highest number of individuals appearing on open space stands followed by those that occurred on *C. mopane* stands and then the ones that were growing on *A. johnsonii* stands (Table 1b). Significant difference was noticed between the numbers of individuals that were

Figure 6. A photograph illustrating part of a 4 m x 10 m quadrat on a sandy soil area without overstory plants (open space stand) growing thereon at Makuya Nature Reserve.

Table 1(a). One-way analysis of variance of biomass of species collected from loam soil areas, biomass of species collected from sandy soil areas, number of species collected from loam soil areas, number of species collected from sandy soil areas, number of individuals of different species collected from loam soil areas and number of individuals of different species collected from sandy soil areas.

Parameter	SS	df	MS	F-values	P
Biomass of species collected from loam soil areas	1816.91	2	908.45	19.30	0.000
Biomass of species collected from sandy soil areas	417.79	2	208.89	12.81	0.00
Number of species collected from loam soil areas	1799.62	2	899.81	185.88	0.00
Number of species collected from sandy soil areas	992.27	2	496.13	435.8	0.00
Number of individuals of different species collected from loam soil areas	9643805.0	2	4821903	3.75	0.03
Number of individuals of different species collected from sandy soil areas	2460144	2	1230072	3.98	0.03

SS refers to sum of squares, df refers to degree of freedom and MS refers to mean of squares. $P < 0.05$.

Table 1(b). Duncan multiple range test analysis of the number of species and species biomass collected from *A. johnsonii* stands, *C. mopane* stands and open space stands. A, B, C and D refer to No. of species that were growing on loam soil areas, biomass of species that were growing on loam soil areas, No. of species that were growing on sandy soil areas and biomass of species that were growing on sandy soil areas respectively.

Treatments	Groups				Replicates
	A	B	C	D	(n)
A. johnsonii vs C. mopane	ns	*	**	*	40
A. johnsonii vs open space	**	**	**	**	40
C. mopane vs open space	**	**	**	**	40

ns, * and ** refer to not significant, significantly different and highly significantly different respectively. $P < 0.05$.

collected from *A. johnsonii* stands versus those that were collected from open space stands and also from those that were collected from *C. mopane* versus those that were collected from open space stands.

DISCUSSION

Although *A. johnsonii* and *C. mopane* shared the same kind of environmental conditions, it was indeed intriguing to note that the wellbeing of both common and non-common factor understory plant species of *A. johnsonii* and *C. mopane* were not matching; the understories of *C. mopane* were more flourishing than those of *A. johnsonii*. Comparing the numbers of plant species that were found in all plots under the canopies of *A. johnsonii* versus those under *C. mopane* canopies, it was somehow visually tempting to conclude that *A. johnsonii* is somehow hindering the growth of its understories. Puzzling was nevertheless the observation where the number of the understory species on *A. johnsonii* stands on loam soil areas was found not to differ significantly from the number of species on *C. mopane* stands also on loam soil areas, the number of species on *A. johnsonii* stands and *C. mopane* stands on sandy soil areas however differed significantly. The probable cause of this manifestation might be because loam soils are rather nutrimentally rich and could therefore confound the true outcome of the expected events in ecosystems, in this instance the real effects of allelopathic materials on understory plants. Plants growing on sandy soils (that is, soils with little or no nutrients at all) infested with allelochemicals are inflicted with allelochemicals only; hence a cogent significant difference between the number of species which are understories of *A. johnsonii* versus those which are understories of *C. mopane* on sandy soil areas.

The species that were growing on the stands of *C. mopane* and on open space stands weighed more than those on the stands of *A. johnsonii* in both loam and sandy soil areas. This is probably an indication that there are some toxic chemicals that are excreted from various parts of *A. johnsonii* that caused the suffering and hence lesser weights of the understory species of *A. johnsonii*. These differences might therefore persuade one to allege that there is better life off *A. johnsonii* stands than in their stands. Even though conditions were found not to be favorable for the majority of the understory species to grow and flourish well under the canopies of *A. johnsonii*, there was at least an exception of about ten percent. Rice (1995) pointed out that the response of plants to allelochemical materials differs from one species to the other due to the genetic make-up of any particular species. The presence of genetic variation in response to environmental cues is necessary for the ability of populations to evolve adaptations to the local environment (Catrine and Ehlers, 2010). Similarly, Ehlers and Thompson (2004) conducted studies where they checked the germination and growth rates of the grass *Bromus erectus* which was planted on the soil collected from thyme chemotype. The results showed *Bromus erectus* adapting well by germinating and growing on the soil collected from thyme chemotype. The above mentioned studies demonstrate that plant allelochemicals can act as a strong selective force driving evolution in plant-plant interaction. Variation in performance and sensitivity among individual plants to a plant allelochemical has been documented (Callaway et al., 2005a). This therefore might imply that even though *A. johnsonii* possess allelochemical materials, some understory species may adapt to such conditions in the proximity of its vicinity.

One would naturally and perhaps normally expect to see vigorous growth and flourishing of understory species occurring on *A. johnsonii* stands because of the amount of litter that is available in such stands. Surprisingly, the opposite was found to be the case under the canopies of *A. johnsonii*. Allelochemical materials possessed by *A. johnsonii* are probably contained in different parts of the tree including leaves, barks, fruits and roots. Decomposition of such different parts in the ground surface under *A. johnsonii* canopies probably results in relatively highest concentration of allelochemical materials in the soil on *A. johnsonii* stands.

The fact that the number of species and species biomass of plant species that were growing on *C. mopane* stands were lesser than those of species that were growing on open space stands on both loam and sandy soils might be an indication that *C. mopane* also releases some allelochemicals that have negative impact on its understories. Such allelochemicals are probably not as deleterious as those possessed by *A. johnsonii* because throughout the current research we found that the understory species of *A. johnsonii* were both less in numbers and species biomass to those of *C. mopane.* On the other hand the lesser number of species on *C. mopane* stands versus those that were on open space stands might be because of the shading of understories by *C. mopane.*

Limiting factors like shading, temperature, water availability, soil type and others may not necessarily be causes of the observed differences in this study because of the fact that both *A. johnsonii* and *C. mopane* stands of this current study were sampled from the same areas. This current study survey revealed that the prevalence of *A. johnsonii* in woodlands chokes its understory plants and such understories might eventually die out.

Conclusion

Since phytochemical materials appear to be fatal to the growth of some plant species in association with those that secrete such allelochemicals, it would therefore be wise for managers of Makuya Nature Reserve and other reserves in South Africa and other countries outside South Africa to take precautionary measures. They may have to reduce the number of species or stands of species such as *A. johnsonii* in the reserves. The understory species are generally grasses, herbs and even shrubs which serve as food for the game like water buck, impalas, nyalas and others. It is therefore, necessary and economical to promote conditions that are conducive to an increase in the number of plants such as grasses, herbs and shrubs for these are food to some animals in the nature reserves.

Conflict of Interest

The authors have not declared any conflict of interests.

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