Animal Health

Review

Sicklebush (*Dichrostachys cinerea*) as a Medicinal Plant

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ABSTRACT

Background: *Dichrostachys cinerea* is considered an invading plant by some and a highly useful plant by others. Within the scope of opportunities offered by the plant, its utilization as natural medicine may be of great interest to veterinary science researchers. **Aim:** To provide abridged information that offers support and orientation regarding the alternative use of this plant in medicine.
Development: There is large evidence of the use of *Dichrostachys cinerea* as a medicinal plant. Different parts of this plant have been used in different treatments, both in humans and animals. In search for the causes of the medicinal effects of the plant, several simple techniques like basic phytochemical screening, and other more sophisticated analytical procedures, have been applied. Its use as animal food has also been studied, as well as the seasonal influence on the medicinal values of the plant.
Conclusions: *Dichrostachys cinerea* is considered an invading plant due to the competition with other crops, but it offers multiple opportunities for use as a medicinal plant. Still, a great deal must be done to search for other veterinary and human medical applications.
Key words: bioactives, photochemistry, alternative medicine, metabolites, medicinal plants (Source: *MeSH*)

INTRODUCTION

According to the manual of African medicinal plants (Iwu, 2014), *Dichrostachys cinerea* is a thorny shrub, which can grow up to eight meters high in some areas. Its brownish crust can be cut off in stripes. The leaves are five to ten cm long, with 8-15 pairs of 4 cm long folioles sharing a gland with the opposing foliole, and are striated. Each foliole is capped with 10-25 pairs of short and narrow leaflets. The thorns can also bear leaves. The inflorescence consists of a large amount

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of pink, white, or mauve filaments, which derive from the leaf axes, on approximately 4 cm stems. The flowers may produce a light fragrance, the sterile flowers are located under the fertile ones, each bearing a yellow stamen.

The roots of the plant fix atmospheric nitrogen, and the leaves are used as a green fertilizer. *Dichrostachys cinerea* can be used as a stabilizer of dunes and the soil (Ecotrop, 2011). Its capacity for adaptation, and pest resistance are linked to the presence of substances with possible medicinal use.

Information about the chemical composition, in relation to the potential use of the plant in nutrition, has been published (Heuzé, Tran, and Giger-Reverdin, 2015; Espinosa *et al.*, 2020), along with data about the bromatological composition of the aerial parts and the pods (Feedipedia, 2015a and 2015b).

The rural population of several developing countries with limited medical resources depends on traditional medicine as a palliative to human and animal diseases. Although commercial pharmaceutical drugs are sometimes accessible in remote areas, sales by inexperienced dealers, and/or without printed instructions, which in addition cannot be read, may lead to misuse. Under these conditions, the utilization of local resources, including ethnoveterinary medicine, is critical to achieve sustainability in agriculture (Mathias, 2007).

Despite the traditional utilization of medicinal species for veterinary use in Cuba by the people, it is not sufficiently studied yet, though in recent years, a remarkable advance has been observed. These results have enabled the detection of 127 species within 113 genera in 51 families, which are referred to as useful to treat ailments of different livestock types (Fiallo, 2001).

Dichrostachys cinerea (sicklebush) has been reported as the main invader of fertile soils, leading to a decline in their use for agriculture (International Network of Model Forests, 2017). It has also been considered a risk for countries with a climate similar to Cuba (SANBI, 2011).

Regardless of its invading characteristic, a more efficient management of the plant needs better practical alternatives for the resources the plant offers. Within the scope of opportunities offered by the plant, its utilization as natural medicine may be of great interest for veterinary science researchers. The aim of this paper is to offer a short guide that provides support in the research of alternative medicinal uses of *Dichrostachys cinerea*, both in animals and humans.

DEVELOPMENT

Experience as natural medicine

Chinsembu and Cheikhyoussef (2016) reported the multiple use of *Dichrostachys cinerea* in alternative medicine. They refer to the utilization of different parts of the plant (roots, crust, cambium, and leaves) treated differently before use.

In countries where the species is commonly found, the roots have been used to heal wounds; the crust is used as a pain killer; the crushed leaves as an emetic; the decocted crust as vermifuge and against blennorrhea (Gomes, Silva, Diniz, and Martins, 2000) to treat venomous snake bites (Lavanya and Ambikapathy, 2016); and the leaves can be used as an inhalant for sore throat (Mendes Ferrão and Cândida, n/a). Its use has also been reported (Indjai, Barbosa, and Catarino, 2014) as medication to treat gastrointestinal diseases in animals, particularly goats, and hens, by placing the plant fruit in their drinking water. There are also reports of its effectiveness against malaria (Kweyamba *et al.*, 2019) and cancer (Mbaveng *et al*., 2019).

Decoction of the crust, and crushed fermented seeds are used as antimycotic, and the infusion of the flower as sedative against insomnia (Godínez-Caraballo and Volpato, 2008).

Some references (Lavanya and Ambikapathy, 2016) deal with the utilization of the crust to treat toothache and dysentery, as well as research on the anesthetic activity shown by the fresh leaves at a higher level than the dry leaves, both having the same concentration of crude extract (Fadhili, 2017).

In Cameroon, six aromatic and medicinal plants, including *Dichrostachys cinerea*, are traditionally used to treat several diseases, such as infections and parasitism (Kamte *et al.*, 2017). Besides, Linforth (n/a) reported anti-inflammatory activity and use against diarrhea, cough, wounds, and insect bites.

Research done with *Dichrostachys cinerea* leaf extracts (Shandukani *et al*., 2018), show their potential as antioxidant and microbial agent, which may be used to treat bacterial diarrhea, and others. The extracts of polar solvents showed an adequate antioxidant and antibacterial action, which encourages researchers to find new possible uses of aqueous extracts. According to these authors, the loss of plant activity when in contact with the gastric juices is of high concern, since it may indicate inefficiencies to attack pathogens in the digestive tract.

A study done by Shandukani *et al.* (2018), suggested that in the presence of a group of metabolites in these extracts can be used to treat diarrhea caused by the ingestion of untreated waters, as a way to eliminate toxicity (Socogins *et al.,* 2015).

Moreover, Aworet-Samseny *et al.* (2011), reported that the root extracts exert a depressive activity on the nervous system of mice, along with a marked protection against induced renal damage, and a significant reduction of kidney stones in rats. The extracts from the roots, crust, and leaves proved anti-diarrheal activity. Tannins have been suggested to be responsible for such effect. These authors also found an *in vitro* antibacterial effect in the leaf and crust extracts.

In Indonesia, more than 40 leguminosae were evaluated, including *Dichrostachys cinerea*, particularly. The bioactive secondary metabolites (Socogins *et al.*, 2014), that include flavonoids, show promise to promote research with these plants for use as functional foods, nutraceutics, and medications (Anton and Jaehong, 2017).

In Cuba, as a result of field work done in seven communities of Camagüey province, ethnobotanical information was submitted in relation to 111 plant species, including sicklebush, as an antiseptic (Beyra *et al.*, 2004).

There is evidence of the use of *Dichrostachys cinerea* as a medicinal plant. Different parts of the plant have been used in different treatments, both in humans and animals.

Study of metabolites

Several different plant characterization studies (including its parts) have been conducted to find an explanation of what leads to the medicinal effects of *Dichrostachys cinerea*, to identify metabolites with known activity.

Table 1 shows the result of the phytochemical screening with different, more or less polarized solvents for extraction. As shown, the leaves are rich in intermediate metabolites with a useful potential for medication.

Table 1. Screening results of phytochemical components of ***Dichrostachys cinerea*** leaves (Lavanya and Ambikapathy, 2016; Shandukani *et al*., 2018).

N	Photochemical component	Ethanol extract	Methanol extract	Chloroform extract
1	Tannins	+	+	+
2	Saponins	-	-	-
3	Flavonoids	+	+	+
4	Alkaloids	+	+	+
5	Antho- and betacyanins	+	+	-
6	Glycosides	+	+	+
7	Phenols	+	+	+
8	Cumarins	+	+	+
9	Steroids and phytosteroids	+	+	-
+ indicates presence - indicates absence				

The metabolites observed in the leaves of *Dichrostachys cinerea* can become active principles for medical use, though other parts from the plant, like the crust, roots, and even flowers and the fruit have been found to be useful as well.

Other authors report the presence of metabolites in these parts, including the following:

A phytochemical study done to different extracts, and 20% tinctures from the crust and roots of *Dichrostachys cinerea* reveals the existence of a wide variety and abundance of secondary metabolites, which include saponins, alkaloids, cumarins, and tannins, which, according to the

authors (Rodés, Peña, and Hermosilla, 2015), are most likely responsible for the biological properties attributed to the plant.

Numerous terpene derivatives, called *dichrotaschys*, have been isolated from the crust. Several of these compounds inhibit farnesyl transferase (Aworet-Samseny *et al.*, 2011).

The methanol extract from leaves, crust from the stem, and roots collected from *Dichrostachys cinerea* trees growing in idle lands, at Jomo Keniata University of Agriculture and Technology (JKUAT), contained all the phytochemicals used for the basic screening, whereas the extract in hot water lacked steroids (Johnstone Neondo *et al*., 2012).

A group of researchers (Rao *et al.*, 2003) isolated a new isomer from mesquitol (2,3-trans-3',4',7,8-tetrahydroxyflavan-3-ol), from *Dichrostachys cinerea*, with excellent yields. It showed anti-free radical activity, inhibiting α-glucosamide, but had no inhibiting activity of xanthine-oxidase. However, the acylation observed in the 3-OH group increased the inhibitory activity against α -glocosidase, and potential inhibitor of xanthine-oxidase.

The results from different published research studies are not contradictory, but the variety of methodologies is broad. Apparently, many of the studies done on metabolites have been directed to the leaves; however, other parts of the plant, such as the crust and roots (less studied), are commonly used in alternative medicine, which paves the way for new research areas.

Some of the methods used in the studies

Different types of drying, crushing, and extraction methods have been studied, including simple and state of the art analytical techniques. For instance, Lavanya and Ambikapathy (2016) worked on leaves dried in the shade, and turned into powder with a pulverizer. The powders underwent successive extractions with organic solvents, such as ethanol, methanol, and chloroform, based on the Soxhlet method. Moreover, in their study, Anita and Malar Retna (2016) selected the extract of chloroform by crushing *Dichrostachys cinerea.* The 9:1 ratio (chloroform: methanol) was selected to detect spots, and evaluate color under ultraviolet light. These authors found that high performance liquid chromatography (HPLC) using the extract of chloroform showed three components with remarkable peak areas.

In a study conducted by Johnstone Neondo *et al*. (2012), the leaves, stem crust, and roots, were washed and dried in the air and sun (27-30°C) for 14 days. The sensitivity of different bacterial strains was measured in terms of inhibition zones, using the disc diffusion assay. The artemia salina lethality test was used to predict the presence of bioactive compounds in the extracts. The methanol extract contained all the phytochemicals, whereas the extract in hot water lacked steroids. No significant differences were found between the extracts in relation to antibacterial screening.

To explain the behavior of the plant, Vijayalakshmi *et al*. (2013) studied the fingerprint of the *Dichrostachys cinerea* extract by Thin Layer Chromatography, then they isolated several fractions using column chromatography. In one of them, β-amirine glycoside was found, which confirmed the use of infrared spectroscopy, H-NMR, C^{13}NMR, and MS.

As stated in previous paragraphs, very simple techniques, like basic phytochemical screening have been useful as analytical procedures, with the utilization of more sophisticated technologies.

Further studies

Apart for its medicinal use, this plant has been subjected to other studies, but no clear conclusions have been drawn in most of them.

According to Ernst *et al.* (1991), the decline of the phenolic concentration takes place in waves throughout the year, which may be related to climatic factors. The monomeric factors make up a large percentage of water-soluble phenolic compounds, which was significantly correlated to total phenols. A general trend toward a positive correlation between high N, P, and K concentrations and the high concentrations of phenolic compounds was observed.

Authors like Scogings, Hjälten, and Skarpe (2011) studied the presence of N, and the action of intermediate metabolites as protectors of plants, in relation to the intensity of leaf browsing (*Dichrostachys cinérea* and others).

A published article on the use of *Dichrostachys cinerea* pods as commercial feedstuff substitute (Marius, 2018) reports the utilization of pods at three levels of inclusion (20, 40, and 60%), compared to a control based on a commercial feedstuff. The weight of goats supplemented with 20% *Dichrostachys cinerea* was similar to the ones fed on the control. The weights of animals supplemented with 40 and 60% of the legume, were lower. Concerning the utilization of sicklebush pod meal as alternative protein supplement in Cuban private pig farmers (Martín-Casas *et al*. 2017) concluded that at least 30% of the dry matter in commercial feedstuffs, can be replaced by this meal without affecting the required growth. They concluded that their low digestibility is not acceptable for intensive rearing.

CONCLUSIONS

Dichrostachys cinerea is considered an invading plant that competes with other crops, but it offers multiple opportunities for use as a medicinal plant.

Still, a great deal must be done to search for other veterinary and human medical alternatives.

REFERENCES

Anita A., & Malar Retna A. (2016). A study on the bioactive compounds present in leaves of *Dichrostachys cinerea*. *Green Chemistry & Technology Letters*, *2*(1). https://pdfs.semanticscholar.org/f645/92361df6077af067d97752a96ace0222a352.pdf

Anton, B., & Jaehong, H. (2017). Leguminous Plants in the Indonesian Archipelago: Traditional Uses and Secondary Metabolites. *Sage Journals Natural Product Communications*. https://journals.sagepub.com/doi/abs/10.1177/1934578X17012003-38

Aworet-Samseny, R.R., Souza, A., Khape, F., Konate, K., & Datte, J.Y. (2011). *Dichrostachys cinerea* (L.) Wight et Arn. (Mimosaceae) hydro-alcoholic extract action on the contractility of tracheal smooth muscle isolated from guinea-pig. *BMC Complementary & Alternative Medicine*, *11*, 23.

Beyra, Ma. del C., Iglesias, E., Ferrándiz, D., Herrera, R., Volpato, G., Godínez, D., … & Álvarez, R. (2004). Estudios etnobotánicos sobre plantas medicinales en la provincia de Camagüey (Cuba). *Anales del Jardín Botánico de Madrid, 61*(2), 185-204. https://edepot.wur.nl/39667

Chinsembu, K. C., & Cheikhyoussef, A. (2016). Indigenous knowledge of Namibia. Cap. 4. The use of medicinal plants as antimicrobial treatment. University of Namibia Press, *Social Science*, 414 pp. https://books.google.com.cu/books?id=G8e_CwAAQBAJ&pg=PA99&lpg=PA99&dq=dichrostachys+cinerea+secondary+metabolites&source=bl&ots=JNHobKLRn3&sig=ACfU3U2pcugMgQZkXryYKzXJM8qotebzg&hl=en&sa=X&ved=2ahUKEwiajpyb1LLlAhXFrFkKHc1VArM4ChDoATAHegQICRAB#v=onepage&q=dichrostachys%20cinerea%20secondary%20metabolites&f=false

Ecotrop (FAO). (2011). Permits the identification and comparison of more than 2300 plant species on environmental requirements in all agro-ecological settings of the world. Textual information also includes a brief description of the species, its use, synonyms, common names and notes. http://ecocrop.fao.org/ecocrop/srv/en/home

Ernst, W.H., Kuiters, A.T., Nelissenand, H.J.M., & Tolsma, D.J. (1991). Seasonal variation in phenolics in several savanna tree species in Botswana. *Acta Bot.Need.*, *40*(1), *63-74*. http://natuurtijdschriften.nl/download?type=document;docid=540813

Espinosa, E., Sifontes, E., Martínez Sáez, S., Pedraza Olivera, R., & León Gonzalez M., (2020). Composición química de hojas peciolos de marabú (*Dichrostachys cinerea*) a dos alturas

secadas a temperatura ambiente y en estufa a 55° C. *Rev. prod. anim., 32(1)*. https://revistas.reduc.edu.cu/index.php/rpa/article/view/e3395

Fadhili, J. (2017). Assessment of anaesthetic efficacy of crude extract from leave of sickle bush (*Dichrostachys cinerea*). A Thesis for the award of the bachelor degree of technology in laboratory science**.** https://www.academia.edu/35988990/ASSESSMENT_OFANAESTHETIC_EFFICACY_OF_CRUDE_EXTRACT_FROM_LEAVE_OF_SICKLE_BUSH_DICHROSTACHYS_CINEREA

Feedipedia. (2015a). Sicklebush (*Dichrostachys cinerea*), aerial part, fresh. https://www.feedipedia.org/node/20078

Feedipedia. (2105b). Sicklebush (*Dichrostachys cinerea*), pods, dry. https://www.feedipedia.org/node/12595

Fiallo, V.R. (2001). Apuntes para la flora económica de Cuba IV. Especies medicinales de uso veterinario. *Revista del Jardín Botánico Nacional*, *22*(2), 221-245. https://www.jstor.org/stable/42597133?seq=1#page_scan_tab_contents

Godínez-Caraballo, D., & Volpato, G., 2008. Plantas medicinales que se venden en el mercado El Río, Camagüey, Cuba. *Rev. Mex. Biodiv.*, *79*(1). http://www.scielo.org.mx/scielo.php?script=sci_arttext&pid=S187034532008000100019

Gomes, T. E., Silva, O., Diniz, A.M., & Martins, S.E. (2000). Plantas medicinais da Guiné-Bissau. Manual prático. Associação para a Cooperação entre os Povos (ACEP, Portugal). Acçãopara o Desenvolvimento (AD, Guiné-Bissau). http://guineabissau.sodepaz.org/bundles/blog/images/introdu%C3%A7ao.pdf

Heuzé V., Tran G., & Giger-Reverdin S. (2015). *Sicklebush (Dichrostachys cinerea)*. Feedipedia, a programme by INRA, CIRAD, AFZ and FAO. https://feedipedia.org/node/298

Indjai, B., Barbosa, C, & Catarino, L. (2014). Mezinhos da terra e curas tradicionais Nas Ilhas de Canhabaque e do Parque Nacioona MarINho João VIeIra e PoIlão. Instituto da Biodiversidade e das Áreas Protegidas Reserva da Biosfera do Arquipélago Bolama Bijagós. Parque Nacional Marinho João Vieira e Poilão, Guiné-Bissau. http://doczz.com.br/doc/492982/mezinhos-da-terra-e-curas-tradicionais

Iwu M.M. (2014). Handbook of African Medicinal Plants. Pharmacognostical Profile of Selected Medicinal Plants. *Dichrostachys cinerea*. *eBook ISBN: 9781466571983*. https://www.routledgehandbooks.com/doi/10.1201/b16292-4#sec3_76

Johnstone Neondo, O., Mweu, C., Kariuki, P., & Wangari, K. (2012). Phytochemical characterization, antibacterial screening and toxicity evaluation of *Dichrostachys cinerea*. *International Journal of Medicinal Plant Research*, *1* (40), 32-37. https://www.researchgate.net/publication/233414584_Phytochemical_characterization_antibcterial_screening_and_toxicity_evaluation_of_Dichrostachys_cinerea

Kamte, S.L.N., Ranjbarian, F., Campagnaro, G.D., Nya, P.C.B., Mbuntcha, H., Woguem, V., … & Maggi, F. (2017). *Trypanosoma brucei* Inhibition by Essential Oils from Medicinal and Aromatic Plants Traditionally Used in Cameroon (Azadirachta indica, Aframomum melegueta, Aframomum daniellii, Clausena anisata, *Dichrostachys cinerea* and Echinops giganteus). *Int J Environ Res Public Health, 14*(7). https://www.ncbi.nlm.nih.gov/pubmed/28684709

Kweyamba, A., Zofou, D., Efange N., Assob, N., Jovin, K., & Nyindo M. (2019). *In vitro* and *in vivo* studies on anti-malarial activity of *Commiphora Africana* and *Dichrostachys cinerea* used by the Maasai in Arusha region, Tanzania. *Malaria Journal*, *18*, 119pp. https://doi.org/10.1186/s12936-019-2752-8

Lavanya, A., & Ambikapathy, V. (2016). Preliminary Qualitative Analysis of Phytoconstituents of *Dichrostachys cinerea* L. *Journal of Pharmacognosy and Phytochemistry,n 5*(3), *86-88*. http://www.phytojournal.com/archives/2016/vol5i-ssue3/PartB/5-2-19-139.pdf

Linforth, D., (S/A). Sickle Bush (*Dichrostachys cinerea*) En: Kruger National Park Articles. https://krugerwildlifesafaris.com/article/sickle-bush-dichrostachys-cinerea.shtml

Marius, L.N., Osafo, I.D.T., Mpofu, E., Lutaaya, K.L., Shiningavamwe, E., Missanjo, V., & Attoh-Kotoku, S. (2018). Effect of Vachellia erioloba and *Dichrostachys cinerea* pod supplementation on performance of does and kids of Namibian Caprivi and Ovambo indigenous goats. *Afr. j. anim. Sci.*, *48*(5). http://www.scielo.org.za/scielo.php?script=sci_arttext&pid=S0375158920180005000003&lng=en&nrm=iso&tlng=en

Martín-Casas, N., Reinoso-Pérez, M.,García-Díaz, J R., Hansen, H.H., & Nielsen, M.O. (2017). Evaluation of the feeding value of *Dichrostachys cinerea* pods for fattening pigs in Cuba. *Trop Anim Health Prod.*, *49*(6):1235-1242. https://www.ncbi.nlm.nih.gov/pubmed/28612173

Mathias, E. (2007). Ethnoveterinary medicine in the era of evidence-based medicine: Mumbo-jumbo or a valuable resource? *The Veterinary Journal*, *173*, 241-242.

Mbaveng, A., Damen, F., Mpetga, S.J., Awouafack, M., Tane, P., Kuete, V., & Efferth, T. (2019). Cytotoxicity of Crude Extract and Isolated Constituents of the *Dichrostachys*

cinerea Bark towards Multifactorial Drug-Resistant Cancer Cells. *Evidence-Based Complementary and Alternative Medicine*. https://doi .org/10.1155/2019/845015

Mendes Ferrão, J., & Cândida, M. (S/A). Dicionário de Plantas Medicinais (on line). Espécies ordenadas pelo nome científico. http://icm.fch.lisboa.ucp.pt/resources/Documentos/CEPCEP/Dicionario,%20Letra%20D.pdf

Rao, R., Tiwari, A., Kumar, S., Reddy S., Ali, A., & Rao, J. (2003). Novel 3-O-acyl mesquitol analogues as free-radical scavengers and enzyme inhibitors: synthesis, biological evaluation and structure-activity relationship. *Bioorganic y Medicinal Chemistry Letters*, *13*(16), 2777. https://read.qxmd.com/read/12873513/novel-3-o-acyl-mesquitol-analogues-as-free-radical-scavengers-and-enzyme-inhibitors-ynthesis-biological-evaluation-and-structure-activity-relationship

Red Internacional de Bosques Modelo. (2017). Manejo de la planta invasora de marabú en Cuba: Cómo sacar lo mejor de lo peor. http://rifm.net/es/bosque-modelo-sabanas-de-manacas

Rodés, S., Peña, D., & Hermosilla, R. (2015). Tamizaje fitoquímico de extractos y tinturas al 20 % de la raíz y corteza de *Dichrostachys cinerea L. (Marabú). Rev Cubana Plant Med*., 20(2). http://scielo.sld.cu/scielo.php?script=sci_arttext&pid=S1028-4796201-5000200002

SANBI (2011). *Dichrostachys cinerea*. South African National Biodiversity Institute, South Africa. http://www.plantzafrica.com/plantcd/dichroscinerea.htm

Scogings, P.F., Hjälten, J., & Skarpe, C. (2011). Secondary metabolites and nutrients of woody plants in relation to browsing intensity in African savannas. Oecologia 167(4), 1063-1073. http://www.academicjournals.org/app/webroot/article/article1380552030-Kaaria%20et%20al.pdf

Shandukani, PD, Tshidino, S.C., Masoko, P., & Moganedi, K.M. (2018). Antibacterial activity and *in situ* efficacy of *Bidens pilosa* Linn and *Dichrostachys cinerea* Wight et Arn extracts against common diarrhoea-causing waterborne bacteria. *BMC Complement Altern Med*., *18*(1), 171. https://www.ncbi.nlm.nih.gov/pubmed/29859076

Socogins, P., Hjalten, J., Skarpe, C., Hattas, D., Zobolo, A., Sziba, L., & Ruke, T. (2014). Nutrient and secondary metabolite concentrations in a savanna are independently affected by large herbivores and shoot growth rate. *Plant Ecol.*, 215, 73-82. https://www.jstor.org/stable/24552070?seq=1#page_scan_tab_contents

Socogins, P., Hjalten, J., Skarpe, C., Hattas, D., Zobolo, A., Sziba, L., & Ruke, T. (2015). Seasonal variations in nutrients and secondary metabolites in semi-arid savannas depend

on year and species. *Journal of Arid Environments 114*, 54-61. https://researchspace.csir.co.za/dspace/bitstream/handle/10204/7976/Scogings_2015.pdf?sequence=1&isAllowed=y

Vijayalakshmi, M., Periyanayagam, K.K., Kavitha, K., & Akilandeshwari, K. (2013). Phytochemical analysis of ethanolic extract of *Dichrostachys cinerea* W and Arn leaves by a thin layer chromatography, high performance thin layer chromatography and column chromatography. *Anc Sci Life*, *32*(4), 227–233. https://www.unboundmedicine.com/medline/citation/24991072/Phytochemical_analysisof_ethanolic_extract_of_Dichrostachys_Cinerea_W_and_Arn_leaves_by_a_thin_layer_chromatography_high_performance_thin_layer_chromatography_and_column_chromatography

AUTHOR CONTRIBUTION

Conception and design of research: SJMS, JAEA; data analysis and interpretation: SJMS, JAEA; redaction of the manuscript: SJMS.

CONFLICT OF INTERESTS

The authors declare no conflict of interests.