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Disease Management in *Cleome gynandra:* A Review

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Abstract:- ***Cleome gynandra*** **known as the African spider plant (Cat's whiskers) is an important leafy vegetable growing in the wild and as a weed in cropping systems throughout tropical and subtropical regions of the world. It has many important uses among culinary and medicinal systems making it a very special agricultural plant that has been neglected as a weed.** ***C. gynandra*** **has been used in place of over the counter medicines to cure ailments and in cropping systems to eliminate pathogens besides being used as a vegetable adding to the diet of mankind. This comes as a cheaper way of acquiring the same components found in those chemicals that are available in the** ***C. gynandra*** **plant. It has an ability of growing and maintaining high photosynthetic activity in elevated temperatures being a C4 plant resulting in high growth rates, it can grow under changing climate scenarios. It fits in all areas that include medicinal and nutritional giving it an important stance to be commercially grown and prove to be an economically important crop as there are increases in organic food markets and medicines and this improves livelihoods especially in developing countries. Commercial production requires tools that can safeguard the crop from being attacked by pests and diseases resulting in massive crop losses. Integrated Pest Management is increasingly taking a better stance considering the increasing resistance to chemicals by pests and an increased acceptance of organic food by many consumers. This pushes towards the promotion of** ***C. gynandra*** **into the main cropping system. This review explores the disease spectrum and management options for diseases of** ***C. gynandra*** **for recommendation for commercial production.**

Keywords:- *Cleome gynandra, Pathogen, Diseases, Commercial production, Integrated Pest Management (IPM)*

I. INTRODUCTION

The growing importance of African indigenous vegetables (AIVs) is due to their resilience against stress, both biotic and abiotic especially in the advent of climate change scenarios. AIVs have not been grown commercially due to low demand in the past. There is increased demand of the AIVs due to different reasons that include increases in demand for organic food and medicines. In Zimbabwe it has been identified by Maroyi (2011) as one of the indigenous edible vegetable. It is one of the plants with leaves that are used for the synthesis of nanoparticles (Asha, Thirunavukkarasu and Rajeshkumar, 2017), and it is used in the Ayurveda, Siddha and Folk systems of medicine (Asha et al., 2017; Lokesha, 2018). *Cleome gynandra* is one of the vegetables that grows naturally in the field among other AIVs, sometimes regarded as weed in some tropical countries, but is a semi-cultivated popular tropical leafy vegetable in many parts of sub-Saharan Africa.

It is used to treat many diseases in their traditional systems and due to its nutritional and antioxidant properties it is used in various culinary systems. *C. gynandra* is found in many parts of the world (Lokesha, 2018). It grows as a weed in paddy fields and also in road sides and in open grasslands and abandoned fields and together with other crops. It can be easily grown and cultivated due to its high protein and amino acids and mineral content, making it a highly economically important crop.

There is potential risk to food security due to the narrowing of the range of domesticated species. Drought, pests and diseases can destroy crops, and the broadening of a food base by cultivation of wild edible plants will be essential, considering the capabilities in the survival chances by wild varieties under environmental challenges. *C. gynandra* has an ability of growing and maintaining high photosynthetic activity in elevated temperatures being a C4 plant resulting in high growth rates and surviving drought and very high temperatures (Adhikari and Paul, 2018; Lokesha, 2018).

Pathogens cause diseases that affect growth and establishment of plant species and their populations and cause subsequent serious losses in crop production systems. This review is an attempt to compile and document information on different aspects of *C. gynanadra* and highlight the need for research on pathogens that affect the growth of *C. gynandra* that will be isolated and characterized using morphological, physiological and molecular attributes to identify the pathogens that exist in different areas of Zimbabwe and other countries. This information is essential to understanding the genetic structure of the pathogen spectrum of *C. gynandra* in the ecological regions of Zimbabwe and abroad providing useful information for pathogen and disease management among biological, cultural and chemical methods for recommendation of *C. gynandra* for commercial production for its sufficient inclusion into the main diet of the country.

A. Importance of Cleome gynandra

Cleome gynandra is an African Indigenous vegetable (AIV) that is important as a traditional vegetable and is constituted in the diet of populations of low to middle income level groups (Lokesha, 2018). AIVs besides being often neglected in research work, they play an important role in curbing hunger and malnutrition (Rensburg *et al.*, 2004). *Cleome gynandra* is among the neglected indigenous species and being among the wild and weedy species, which have the potential to be cultivated (Rensburg *et al.*, 2004). They are sources of micronutrients that include vitamins A and C, iron (Rensburg et al., 2004) and vitamins B complex, and vitamin E and calcium.

It has many important uses among culinary and medicinal systems making it a very special agricultural plant that has been neglected as a weed (Adhikari and Paul, 2018). Despite commitments made worldwide to reduce and eliminate micronutrients malnutrition at different occasions like the International Conference on Nutrition (ICN) in 1992 and World Food Summit in 1996, there are still looming high rates of micronutrients malnutrition persisting in Africa (Rensburg *et al.*, 2004). AIVs constitute a big portion in farming and consumption systems throughout Africa. AIVs provide basic nutrients that constitute a greater portion of micronutrients as compared to exotic vegetables. Being important sources of micronutrients they are crucial to food security, curbing hunger in rural areas and among the resource poor consumers and particularly important during famine and natural disasters (Rensburg *et al.*, 2004).

AIVs grow in the wild or as weed in cultivated areas. They have been semi-cultivated or cultivated as a result of domestication in areas where cultivation of exotic vegetables is difficult and expensive (Rensburg et al., 2004). *C gynandra* is a well-known plant with traditional and pharmacological importance (Adhikari and Paul, 2018). *C. gynandra* has been used to cure different ailments in many areas of the world where it has been included in the Ayurveda, Siddha and Folk systems of medicine (Asha et al., 2017; Lokesha, 2018). It is also used to control plant diseases in agricultural systems, where the extracts are used to stop and prevent bacterial, and fungal growth, and they are antimicrobial (Lokesha, 2018). Chongori et al., (2016) used *C. gynandra* at flowering stage as a bio fumigant to control weeds during turf grass establishment and it supressed weeds successfully just like synthetic herbicides.

Though AIVs are important in the diet they have been neglected due to inadequate research and development (Rensburg et al., 2004). AIVs have been considered as a vegetable for the poor people. This leads to under exploitation of the AIVs. This displacement and decline in their production will have a detrimental impact on the nutritional status of households and the income particularly of the women farmers who constitute the primary producers as well as consumers and sellers of these vegetables. Rensburg et al, (2004), recommends for high priority research to be done on those AIVs crops. *C. gynandra* has high protein and amino acids, minerals content which makes it a highly economically important weed which can be grown and cultivated easily.

C. gynandra has survived evolutionary competition under natural/wild pathosystems. The host species has not been impaired by its parasites resulting in its evolutionary survival (Robinson, 1976). Plants represent different pathosytems, in which they respond differently to pathogen responds (Mahlein, 2015). The existence and survival of *C. gynandra* in the wild is assumed to depend on the ability of some plant species to the secondary metabolites they produce that effectively ward off insect, microbes and nematodes by William et al., (1989) in Williams et al., (2003).

Introduction of AIVs into commercial crop production requires measures that needs to be taken to ensure a successful crop by ensuring pests and disease management. Pest control remains one of the most important farm operations in crop production cycles.

B. Cleome gynandra and its Synonyms

Cleome L. is a large genus which includes 150 species which grown well in the tropical and subtropical countries (Stevens, 2012). One of the most interesting plant family that is under the researchers' lance is Cleomaceae family. They are interested, especially on Cleome genus because the selected genus extracts showed significant anticancer and antimicrobial activities (Bose et al., 2011). There are 39 synonyms listed in the plant list from different countries in 2013 conference proceedings. *C. gynandra* have 9 synonyms listed by (Adhikari and Paul, 2018) that include *Gynandropsis gynandra* (L.) Briq., *Gymnogonia pentaphylla* (L.) R. Br. ex Steud., *Gynandropsis pentaphylla* Blanco., *Cleome pentaphylla* L.,*Cleome pentaphylla* var. glabra Kuntze., *Pedicellaria pentaphylla* (L.) Schrank., *Pedicellaria pentaphylla* (L.) Schrank., *Pedicellaria triphylla* (L.) Pax., *Gynandropsis pentaphylla* (L.) DC., *Podogyne pentaphylla* (L.) Hoffmanns., *Gynandropsis heterotricha* DC., *Gynandropsis glandulosa* C. Presl., *Cleome acuta Schumach*. and Thonn. and 7 listed, 6 are among Adhikari & Paul, (2018)'s list except *G. denticulata* DC. 8 synonyms and 5 are among Adhikari & Paul, (2018)'s list except *Cleome alliacea* Blanco, *Cleome alliodora* Blanco and *Sinapistrum pentaphyllum* Medic. Among these synonyms some have been identified to be attacked by certain pathogens which cause diseases.

II. LITERATURE REVIEW

A. Pathogens that Affect Cleome gynandra

Pathogens and pests that appear and exist on *C. gynandra* crop pathosystems have been identified in Odisha India where *Cercospora uramensis* a mildew fungi were observed from leaves of *Cleome rutidosperma* a synonym of *C. gynandra* and first reported by Atheya and Mathur (1966), but not managed using different management options. Cleome species has been affected by some identified pathogens from fungi and virus groups that affect their growth. *C. gynandra* has been found to be affected by fungal diseases like powdery mildews caused by *Sphaerotheca fuligenea* which were observed by Reddy and Reddi (1980) in India. Leaf spot disease caused by *Oidiopsis taurica* found by Singh (1983) in India. Purple stemmed *C. gynandra* besides being nutritious and tolerant to insects it is susceptible to diseases caused by mildew (Lokesha, 2018). Nayak et al., (2018) observed some powdery mildew caused by *Podosphaera xanthii* to affect *Cleome rutidosperma* a synonym of *C. gynandra* in India. Raj et al., (2010) identified leaf curl disease on *C. gynandra* which is caused by a virus called *Ageratum* enation in Northern India. Dube et al., (2018) has identified and confirmed through pathogenicity that *Xanthomonas campestris, Alternaria alternata, Fusarium oxysporum* and *Bacillus* species cause diseases on *C. gynandra* species, but the diseases they cause have not been discussed and managed in Zimbabwe. Dube et al., (2018) identified those pathogens in three provinces of Zimbabwe and the pathogens were morphologically identified only on seeds. Table 1 shows pathogens and diseases that affect *C. gynandra* plant pathosystems and their synonyms that have been identified in different countries.

Table 1 Pathogen and their Diseases that Affect *C.spps*. Plant Pathosystems and their Distribution.

Pathogen	**Disease**	**Control/ management used**	**Species/plant affected**	**Plant parts affected**	**Location/ phathosystems**	**Country identified**	**Reference**
Cercospora uramensis	Mildew (fungi)	None	*Cleome rutidosperma*	Leaf surfaces	Different locations	Odisha state India	Atheya and Mathur (1966)
Sphaerotheca fuliginea	Powdery mildew	None	*Cleome gynandra*	Leaf surfaces	Different locations	India	Reddy and Reddi, (1980)
Oidiopsis taurica	Leaf spot	None	*Cleome gynandra*	leaf	Different locations, close to human dwellings	India	Singh, (1983)
-	Mildew	None	Purple stemmed *Cleome gynandra*	Leaf surfaces	Different locations		Lokesha, (2018)
Xanthomonas campestris	-	None	*Cleome gynandra*	Seeds, whole plant	Seeds collected from different locations and seed houses	Zimbabwe	Dube et al., (2018)
Alternaria alternate	-	None	*Cleome gynandra*	Seeds, whole plant	Seeds collected from different locations and seed houses	Zimbabwe	Dube et al., (2018)
Fusarium oxysporum	-	None	*Cleome gynandra*	Seeds, whole plant	Seeds collected from different locations and seed houses	Zimbabwe	Dube et al., (2018)
Bacillus sp	-	None	*Cleome gynandra*	Seeds, whole plant	Seeds collected from different locations and seed houses	Zimbabwe	Dube et al., (2018)
Podosphaera xanthii	Powdery mildew	None	*Cleome rutidosperma*	Leaf surfaces	Different locations	Ordisha state, India	Nayak et al., (2018)
Ageratum enation	Leaf curl (virus)	None	*Cleome gynandra*	Leaf surfaces	Banks of Gomti River in Gomitnagar	Northern India	Raj et al., (2010)

Source Author

However, as shown in a study by .Weli et al (2020), Cleome aerial parts have antimicrobial and cytotoxic properties that inhibit growth of two Gram positive (+) bacteria: *Staphylococcus aurous* (*S. aurous*), and *Enterococcus faecalis* (*E. faecalis*) and two Gram negative (−) bacteria: *Haemophilus Influenza* (*H. Influenza*), and *Escherichia coli* (*E. coli*).

B. Knowledge Gaps and Future Pespectives on C. gynandra Disease Management

To our knowledge not much has been done on pathogens that affect this potential crop. There is therefore need to work and identify other pathogens that are found on *C. gynandra* in other places given the differences in geographical location and also seasonal differences that can promote growth and development of other different pathogens as cited by Elad & Pertot, (2014) where they indicated that predicted climatic changes are expected to affect pathogen development and survival rates and modify host susceptibility, resulting in changes in the impact of diseases on crops, hence the effects of these climatic changes will differ by pathosystem and geographical region.
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There are also pathogens that affect and cause diseases on other parts of the plant including roots, stems, leaves, flowers and seeds, and all these need to be explored to consolidate the pathogen spectra that affect the whole plant of *C. gynandra*. There is also a need to work and identify pathogens molecularly considering that some pathogens may have many strains that can morphologically appear the

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same but difficult to characterize as was experienced in characterization of *Trichoderma* strains at morphological stages which required the need to use other methods done by Grondona et al., (1997) to characterise the species into many strains that have different biological control attributes.

Pathogens that appear and exist in some crops have not yet been identified and managed using different management options and requires further research where *C. gynandra* is the crop of interest for further research on characterization of pests and diseases that affects its growth, due to its widespread demand. Following precision agricultural practices, there is future research that can be conducted where common methods of pathogen identification described by Mahlein, 2015, where human ratters do disease estimates that are followed by microscopic evaluation of morphological characteristics as well as molecular, serological and microbiological features to diagnose and detect plant pathogens that affect *C. gynandra* pathogens in different pathosystems.

- *Potential Management Options for Diseases In C. gynandra*

Good progress has been made regarding disease control/ management using innovative/improved cultural/agronomic practices in large, medium and small-scale farm settings. Integration of cultural practices with sensitive and specific diagnostic tools, transgenic approaches and conventional breeding may offer a more sustainable and environmentally friendly approach to control *Cleome* diseases. *C. gynandra* pathogens and diseases have been identified, but they have not been controlled and managed in their environments. Some pathogens have been found to be virulent on *C. gynandra* by Dube et al., (2018) but the disease they cause have not been discussed. Nayak et al., (2018) has also cited some pathogens that cause diseases on *C. gynandra* but there are no management options that have been deployed to control these pathogens on the plant. There are many management options that have been deployed in pathogen control of other plants species, which will be adopted to try and control pathogens that cause diseases in *C. gynandra*. There are chemical method and biological methods and cultural methods that will be tried and tested on the pathogens that affect *C. gynandra* to try and come up with the best options in managing the pathogens.

Pest control strategies require proper identification of the pest before being deployed on the crop being grown. Using Integrated Pest Management (IPM) gives options that can be used to eliminate pests with the choice where the best method has to be more effective and being the least harmful to the environment or people who may come in contact with it (Agrios, 2004). IPM sustainably controls pests in an environmentally friendly manner.

To maintain quality and abundance of food, feed and fibre produced by growers there is need to control plant diseases. Pest control remains one of the most important farm operations in any crop production cycle (Alalade *et al*., 2017). Pest control saves crops from damage and reduces losses in the field, however the methods used to control pests also depends with the scale of crop production. Three methods of pest control are mainly used with pesticides or chemical/ pesticide use being the most practiced, and used as the first line of pest control, then cultural and biological control methods (Alalade *et al.*, 2017).

- *Chemical Control*

Great improvements have been made by the use of chemical fertilizers and pesticides in crop productivity and quality over the past 100 years, however excessive use and misuse of agrochemicals has caused environmental pollution, and has detrimental effects on health (Alalade et al., 2017). Fungicides can control and eradicate fungal pathogens. Fungicides have different modes of action such that they cannot completely eradicate some other fungi depending on the stage and rate of infection (Caffi and Rossi, 2018). Fungicides modes of action works towards their targeted action to control the fungi in question, there are contact, protectant fungicides, and contact protectant systemic fungicides and also they have different target sites and different rates of transportation from application site (Caffi and Rossi, 2018). Fungicides are grouped according to their mode of action and their targeted pathogen (Caffi and Rossi, 2018). There are 23 different fungicide families or groups eg benzimidazole in group 1 trading as thiophanate-methyl and benomyl, dicaboximide group 2 trading as iprodione, phenylamides (PA) in group 4 trading as acylamines (metalaxyl, futalaxyl, benalaxyl), quinone outside inhibitor (QoI) in group 11 trading as azoxystrobin and fenamidone etc. IPM is an alternative approach against the traditional approach of continuous spraying of fungicides to control fungi on plants (Caffi and Rossi, 2018). The control of diseases that affect *C. gynandra* will dwell on IPM and less on chemical control as a standalone measure. Chemical control measures are being limited by environmental contamination, development of pesticide resistance by some pathogens due to use of single mode of action fungicides without using different modes (Caffi and Rossi, 2018) and also not following IPM principles, and the tightening in regulations to register for use among other limits. The use of chemical pesticides on plant pathogens using DDT was accepted but latter rejected due to its teratogenic effects on the environment in the 1960s by Bretveld et al., (2006) in (Alalade *et al.*, 2017). This aspect was also discussed and new lesser toxic chemicals have been developed and used, but the use of biological control agents has proved to be more environmental friendly and effective (Alalade et al., 2017). Chemical pesticides have formulations which work differently on pathogens. To avoid resistance by pathogens to the pesticides there is need to use different chemical formulations when treating the same pathogen at different times. This is to be done on disease management on *C. gynandra* to reduce any possible hazards.

Crop damage has increased from 7% in the 1940's to 13% in the 1980's, due to increased pesticide resistance, secondary crop outbreaks, destruction of natural enemies, increased environmental concerns due environmental pollution as a result of misuse and the detrimental effects of the pesticides on health (Alalade *et al.*, 2017), and high

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pesticide costs, resulting in shifts to the use of more environmentally friendly and cheap control strategies of using biological control methods together with other pest control strategies under Integrated Pest Management.

Cultural and biological control methods of pest control promised to be more environmentally friendly (Alalade *et al.*, 2017) though they do not eradicate the pathogen but control it, so it is manageable and natural and cost effective (Alalade et al., 2017), they work hand in hand in IPM.

- *Biological Control*

There are many biological control agents that are listed and the types of antibiotics they produce to prevent the living of particular pathogens where he indicates that *Pseudomonas fluorescence* produces 2.4 diacetyl phloroglucinol that controls damping off disease caused by *Pythium* species identified. *Agrobacterium radiobacter* produces Agrocin 84 antibiotic that treats crown gall caused by *Agrobacterium tumerfaciens*. *Bacillus subtilis* AU195 produces Bacillomycin D which treats Aflatoxin contamination caused by *Aspergillus flavus* identified by Moyne et al., (2001). *Bacillus amyloliquefaciens* FZB42 produces Bacillomycin Fengycin which treats wilt caused by *Fusarium Oxysporum* identified by Koumoutsi et al., (2004). *Lysobacter* species strain SB-K88 produces Xanthobaccin A which control damping off caused by *Aphanomyces codilioides* identified by Islam et al., (2005).

Trichoderma virens produces Gliotoxin which controls root rots caused by *Rhizoctonia solani* identified by Wilhite et al., (2001). *Pantoea agglomerans* C9-1 produces Herbicolin which treats fire blight caused by *Erwinia amylovora* identified by Wright et al., (2001). *B subtilis* QST713 produces Iturin A which treats Damping off disease caused by *Botrytis cinerea* and *R. solani* identified by Paulitz & Belanger, 2001; Kloepper et al., 2004). *B. subtilis* BBG100 produce Mycosubtilin which treats Damping off disease caused by *Pythium aphanidermatum* identified by Leclere et al., (2005). *P. fluorescens* PF-5 produces pyrroluteorin pyrrolnitrin which treats Damping off caused by *Pythium ultimum* and *R. solani* identified by Howell & Stipanovic, (1980). *P. fluorescens* 2-79 and 30-84 produces phenazines which treats all diseases caused by *Gaumannomyces graminis* var. *tritici* identified by Thomashow et al., (1990). *Burkholderia cepacia* produces Purrolnitrin pseudane which controls Damping off and Rice blast diseases caused by *R. solani* and *Pyricularia Oryzae* respectively identified by Yoshihisha et al., (1989). *Bacillus cereus* UW85 produces zwittermicinA which treats damping off disease caused by *Phytophthora medicaginis* and *P. aphanidermatum* identified by Smith et al., (1993).

Biological control agent *Trichoderma* is an endophytic fungus which is commonly found both in cultivated and non-cultivated soils (Zahran *et al.*, 2015). *Trichoderma hazianum* Rifai has strains that control plant pathogenic fungi and viruses as a biological agent (Grondona *et al.*, 1997). A variety of plant pathogenic fungi such as *Rhizoctonia solani* and *Fusarium verticillioides* species are biologically controlled by *Trichoderma,* which produces protease and chitinase during the parasitic interactions that degrade the cell wall of the pathogens (Zahran *et al.*, 2015). Some *Trichoderma* species control fungi and bacteria on tree wounds and it has been used to treat Dutch Elm disease. Reference will be made to the above biological control agents according to their availability to try and use them to control identified pathogens that affect *C. gynandra* growth.

- *Cultural Control*

In regions, villages or farms where diseases are not present, the first line of defense is to avoid introducing them, i.e., through exclusion. Use of clean planting material and good sanitation procedures need to be always coupled to quarantine methods. Infected plant material that was not multiplication detected during diagnostic indexing, can be readily discarded during the process leading to its total disappearance from the system. Where a disease is already endemic, control options should focus on a systematic area-wide approach, with the adoption of a combination of activities such as: limitation of access of animals, workers/laborers and equipment from and to the infected fields, regular disinfection of farm tools, implementing disinfection points in frequent access points, killing and removing diseased and neighboring plants, building channels around the infected plants. Cultural control practices can be used to control the pest by altering the environment and conditions in which the pathogen grows. There are methods that include selection of varieties that are resistant to pathogen attack, planting and harvesting times, use of trap crops, irrigation, crop rotation, use of different types of mulches, level of fertilization, sanitation, micro climate modification, mulching, plant population management (Narayanasamy, 2011). Genetically exploration of methods that have been used in other circumstances will help in the control of *C. gynandra* pathogens and diseases.

III. CONCLUSSION

C. gynandra exists as a weed regardless of its wide uses in the pharmaceutical, medical, and culinary fields and this has resulted in little research being conducted on the pathogens that affect and cause diseases on the plant. It has only been researched in India and some parts of Zimbabwe, where there is need to intensify the research on the pathogens that cause diseases on *C. gynandra* which has proved to be a crop of economic importance given that it survives harsh conditions during changing climate scenarios in different pathosystems and it can be mainstreamed in the diet system to curb hunger.

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