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A Critical Analysis of Terrestrial Weed Control: Utilizing Composting and Anaerobic Digestion for Managing *Chromolaena odorata*

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Abstract:- *Chromolaena odorata*, a notorious invasive weed, disrupts ecosystems, agriculture, and economies worldwide. Its allelopathic tendencies hinder the growth of neighboring plants, leading to detrimental effects on crops such as chili peppers, tomatoes, soybeans, and shallots. Conventional control methods prove ineffective and unsustainable, given their economic and environmental drawbacks. Eradicating this fast-spreading weed presents significant challenges. This paper provides a comprehensive review of composting and anaerobic digestion as promising strategies for managing and controlling *Chromolaena odorata*. Additionally, its phytoremediation properties suggest potential for use in metal recovery efforts.

Keywords:- *Allelopathy, Anaerobic Digestion, Chromolaena Odorata, Composting, Phytoremediation.*

I. INTRODUCTION

Chromolaena odorata, also commonly known as Siam weed, is one of the notorious invasive weeds on the planet. It causes a severe threat to the environment and ecosystem in most parts of the world- Central and Western Africa, India, Australia, Southeast Asia and the Pacific islands [1]. Siam weed is indigenous to Central and South America and is later spread to various places of the world where it becomes invasive [2]. *Chromolaena odorata* typically thrives in regions located between 30°N and 30°S latitude and in places where the annual rainfall is less than 200 cm. The optimal temperature range for the weed's growth is typically between 20°C and 37°C [3]. In Africa, Siam weed was first introduced to Nigeria and later invaded to other countries such as Cameroon, Ghana etc. [4]. In Asia, it is grown in several countries, including India, China, Vietnam and Thailand [3] [5]. It is also present in Southeast Asian countries like Cambodia, Laos and Myanmar [1]. Siam weed is an invasive plant species that is widely distributed in India. It is known to grow in different parts of northeastern India, including Arunachal Himalayas region, where it is grown widely in forest areas, agricultural lands and along roadsides [6].

Chromolaena odorata is a perennial plant species that grows rapidly and it belongs to the Asteraceae family [5]. It's a shrub capable of reaching heights of up to 3 meters, with woody stems that are densely covered with hairs and small thorns [7]. A system of lateral roots, long branches with little sub-branching, 4mm long brown-grey to black achenes and 5-6 mm long pappus are some characteristics of the plant (Liogier,1997). The weed's reproduction mode is through seeds, which are dispersed by the mode of anemochory [6]. As many as 80,000 seeds can be produced by a single *Chromolaena odorata* shrub in a single season, aiding in a vast invasion of land [8]. It adapts and establishes quickly and covers the crop and natural vegetation. Once they began to spread, these weeds infested open spaces brutally, competing with herbs, grass, and shrubs. It frequently grows along roadsides, sides of railway tracks, along riverbanks, on defunct farms, and in neglected pastures [3].

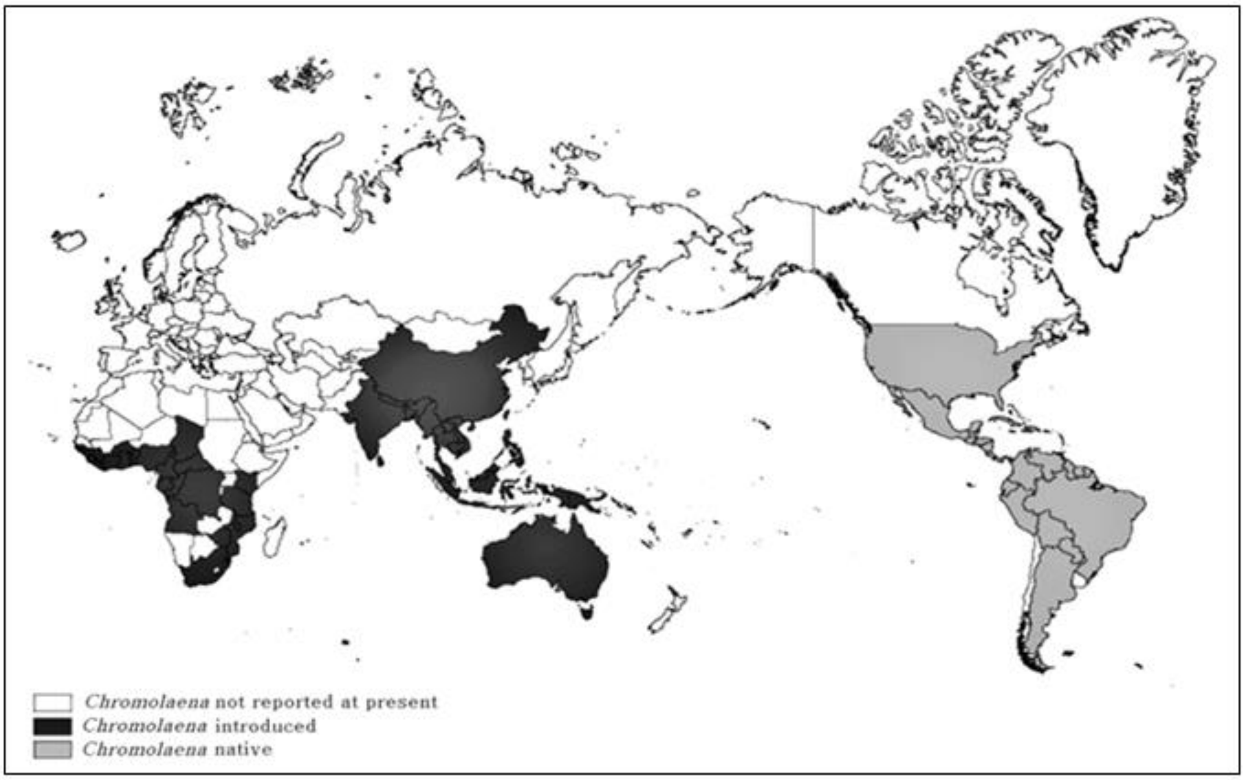

Fig 1. Global Geographic Distribution of *Chromolaena odorata* as reported by Mandal and Joshi, 2014.

II. PHYTOREMEDIATION

Phytoremediation is the technique of using plants to remove or mitigate pollutants from soil, water, or air. It is a natural, cost-effective, and sustainable method for environmental cleanup [9]. *Chromolaena odorata* has the potential for phytoremediation. The metal toxicity of plants due to the presence of heavy metals is caused by the replacement of essential metals in the cation exchange site [10]. *Chromolaena odorata* has the potential to accumulate different heavy metals, and its order of accumulation is also different in the nutrient solution medium and the soil. The accumulation of metals is higher in roots as compared to that of the stems and leaves [11]. It can uptake Cadmium from cadmium-polluted soils and hydroponic mediums without showing inhibition in growth [12]. It is also a hyperaccumulator of lead which could endure soil lead concentrations up to 100000 mg kg-1 and a translocation factor of 7.6 [5].

III. ALLELOPATHIC PROPERTIES

Some of the weeds deploy chemical stress on other plants growing together by the action of phytotoxic root exudates and other leachates from the debris of the weed accumulated in the soil [13]. *Chromolaena odorata* is also known to possess allelopathic properties. Allelopathic properties of a plant are the properties by which it releases chemicals that inhibit the growth or development of other plants growing together. These chemicals (allelochemicals) can be set free to the roots, leaves and decomposing plant material. Certain crops, including maize, cowpea, and soybean, are hindered from germinating and growing by the weed's aqueous abstract., which could be due to the release of phenolic compounds on the abstract [14]. *Chromolaena odorata* is also learned to show allelopathic properties even in soil microorganisms. The aqueous abstract of the weed roots inhibited the growth of microorganisms, including some bacteria and fungi [15]. The inhibition of plant growth depends on the concentration of the weed extract, and the amount of inhibition is comparatively greater for extract obtained from shoots than that for the extract obtained from the roots [16]. Even the extract of debris from the weed has been reported to show inhibition in seed germination and a decrease in plant height, leaf numbers and leaf areas in test specimens of rice, mustard and groundnut [17].

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Table 1: Effect of allelopathic potential of *Chromolaena odorata* on various crops.

Name of the test species	Siam weed extract	Effect on test species	References
Rice, mustard and ground nut	Debris of the weed	Reduced in seed germination, plant height, leaf numbers, leaf area and seedling dry weight	[17]
Cowpea (Vigna unguiculata L. Walp) 1.IT99K-573-1-1 2. IT07K -292-10	Roots and shoots	Reduction of seed germination is higher in shoot extract. 1. Reduction of seed germination by 78% 2. Reduction of seed germination by 75%	[16]
Chilli, Cucumber, Chinese Cabbage and Rape	Leaf debris, leaves extract and contaminated soil	Leave debris affected the emergence and dry weight of the species Leaves extract reduced the germination of the test species In the weed contamination soil, dry weight of cabbage and chili decreased	[18]
Vigna radiata	Methanolic leaves extract	Reduction in root and shoot elongation 80% methanolic extract effect seed germination	[19]
Rice, Groundnut, Chickpea and Mustard	Leaf, stem and root	Leave extract affected the test species the most. 24.7% inhibition for groundnut and rice which was maximum	[20]
Tomato (Lycopersicum esculentum)	Exudates from vegetative part	Inhibitory effect in seed germination. Greater time in soaking of weed exudates reduced the inhibitory effect	[21]

IV. MANAGEMENT OF *CHROMOLAENA ODORATA*

Interest has been shown in controlling invasive weeds with the knowledge of its impact on economic and environmental costs [22]. *Chromolaena odorata*, being highly invasive, is very difficult to control. It, therefore, requires dealing with several methods of treatment. It can be controlled by biological, physical, cultural and chemical methods.

Biological control is one of the methods which was adopted for the management of invasive weeds. *Pareuchaetes pseudoinsulata* was reportedly successful in a few countries like Sri Lanka, with a 17% establishment in the 1970s and early 1980s and later increased up to around 75%. At the same time, the use of *Apion brunneonigrum* for the control was assessed to be failed [23]. Gall fly and *Acalius adoratus* were also reported to establish in Indonesia and south and southeast Asia, respectively [24]. Leaf-mining moth *Pareuchaetes insulata* also reportedly achieved localized damage to the weed [25].

Slashing the upper portion of the weed and uprooting the roots is one of the mechanical controls of the weed. However, it is ineffective because the roots are coppice profusely beneath the soil. Mechanical uprooting of seeds is not feasible from the economical aspect and complications of the process as it may cause soil disturbance, erosion and exposure of seeds [26]. Burning of the weed was reported to be practiced in grasslands in South Africa annually, where mature weed plants were killed, and seeds were destroyed [27]. The use of this method is not effective as it will also destroy the other species growing together. Hand-pulling and uprooting the young plants are not fruitful as they need to be done often due to the rapid regrowth of the weed [27].

When it comes to the chemical methods of controlling weed, using herbicides at the early rapid growth time of the weed and after slashing the young shoot [28]. The use of foliar herbicides- triclopyr/picloram was less effective in affecting seed viability and a little inhibition in seed germination [29]. However, Foliar sprays of 2,4-D ester, picloram, 2,4,5-T and dimethyl ether were 90% effective if applied in early summer, but 2,4-D was susceptible to vegetable crops and thus, banned to use in South Africa [26]. Herbicides like 2,4-D; glyphosate; asulam; paraquat; triclopyr; imazapyr; metsulfuron; tebuthiuron; atrazine; picloram, and classical combinations such as picloram+2,4-D; dicamba+2,4-D were reported to be used as pre-emergence treatment while glyphosate or combinations including picloram, dicamba or triclopyr could be used repeatedly for mature plants [28]. Some of chemicals, including 2,4-D, atrazine, and paraquat, are probably only efficient on seedlings or young plants. The use of herbicides may, however, affect non-target plants and vegetables. It may also destroy the soil fauna and pollute the soil water when it percolates.

The different control methods are not highly efficient. And as a result of this, there will always be a residual part of the weed, which can cause a rapid regrowth in the area. The invasive nature of the weed makes eradication an impossible task. The deployment of mechanical tools and machines may be restricted to the weather and soil conditions and may have limitations from an economic point of perspective. As an

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efficient disposal method of terrestrial weed, using the weed biomass to recycle a valuable product may be considered using eco-friendly techniques like composting and anaerobic digestion.

A. Composting as Management Technique

One of the finest methods for controlling noxious invasive weeds is composting. It can be done in the conventional composting method and vermicomposting. Different researchers concluded that high-quality compost was obtained from composting various noxious and invasive weeds. Some of the weeds used for conducting composting works were *Parthenium hysterophorus* and *Lantana camara* [30], *Hydrilla verticillate* [31], *Ageratum conyzoids* [32], *Mikania micrantha kunth* [33] and *Eichhornia crassipes* [34] etc.

Only some work has been done on the composting of *Chromolaena odorata*. When vermicomposting of the weed with cow dung as the inoculum is done by using *Eisenia fetida* for 30 days in different trial mixes of 50%, 60%, 70%, 80%, 90% and 100%, it results in obtaining a substantial shift in biomass, number and cocoon production of the earthworm. In all the mix samples, there is a decrease in parameters like C/N ratio, TOC and pH and an increase in EC and TKN values are recorded. A Mix of 60:40 of weed and cow dung is noted to have the best result in the vermicompost. Biodegradation of complex organic substances shows the maturation of the vermicompost so obtained as is recorded by the analysis using FT-IR spectroscopy [35]. Thus, *Chromolaena odorata* may be efficiently used for composting with a proper combination of a suitable inoculum like cow dung, poultry manure etc. Siam weed compost blended with a biocontrol agent of avirulent Fusarium Oxysporum F.Sp. cepae exhibits better growth and increases yield by 26% in shallot cultivation compared to the utilization of inorganic fertilizers [36]. Another researcher [37] found good improvement in parameters of the tomato plant- number of leaves, branches, leaf area, highest fruit set and fruit size when *Chromolaena odorata* compost along with nitrogen in the form of NPK fertilizers at different ratios of combination. Similarly, a positive impact was achieved by applying Siam weed compost in chili paper vegetation. Higher growth and yield of chili pepper were reported while applying the compost of 20-ton ha-1 in contrast to the application of urea alone [38], [39].

Table 2: Physiochemical Parameters of *Chromolaena odorata.*

Properties	*Chromolaena odorata*
Electrical Conductivity (ms/cm)	2.01 ± 0.06
pH	8.31 ± 0.10
Total Organic Carbon (gm/kg)	456.27 ± 0.13
Total Kjeldahl Nitrogen (gm/kg)	15.13 ± 0.09
C/N ratio	30.16 ± 1.44

B. Anaerobic Digestion as Another Management Technique

Anaerobic digestion is another alternative that may effectively manage the terrestrial invasive weeds, while energy recovery can also be engineered [40]. It is a process of stabilizing and breaking down organic matter into methane and carbon dioxide (biogas, a renewable energy source) under anaerobic conditions by anaerobic micro-organisms [41]. The use of terrestrial invasive weeds- *Lantana camara*, *Parthenium hysterophorus* and *Ageratum conyzoides* as a substrate proved to be more efficient in enhancing the higher yield of biogas in anaerobic digestion when they are co-digested with food waste at proper food/micro-organisms (F/M) ratios [42]. Another researcher also demonstrated the beneficial potential of utilizing aquatic plants like water hyacinth and salvinia. [43]. Only a little analysis has been done on the anaerobic digestion of *Chromolaena odorata*. The substrates pre-treated by a combination of mechanical and thermo-alkaline treatment recorded higher production of biogas than pre-treated substrates mechanically [44]. The enhancement of biogas production results from the solubilization of lignin, cellulose and hemicellulose complex structures [45]. Moreover, another paper shows the better yielding of biogas when the weed biomass (Siam weed) mixed with poultry manure is co-digested with food waste after the weed is pre-treated with a series of mechanical and thermo-alkaline treatment [4]. The addition of nutrient-rich poultry manure (inoculum), i.e., high nitrogen content and enhancing enzyme activities, helps in the rapid breakdown of substrates and higher biogas yield [20].

Table 3. Work Done on the Recycling of Weed Biomass of Siam Weed

Author and Year	Work Done
Ganguly et al., 2022	Management of Siam weed through vermicomposting
Dahunsi et al., 2017	Co-digestion of Siam weed along with poultry manure
Setyowati et al., 2017[a]	Effect of weed based organic compost (Siam weed and wedelia)
Setyowati et al., 2017[b]	Impact of wedelia and Siam weed compost application at different times on the growth and output of chili peppers
Akinrinola and Tijani-Eniola, 2022	Impact of Siam weed compost and synthetic fertilizers on tomato growth and yield
Dahunsi et al., 2018	Production of biogas from Siam weed through anaerobic digestion
Nugroho et al., 2019	Effect on growth and yield of organic shallot combining with biocontrol agent

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V. CONCLUSION

The rapid expansion of *Chromolaena odorata* (Siam weed), causes a lot of damage to the ecology, agricultural activities and indigenous species. The conventional ways of management- mechanical, cultural, chemical and biological controls are not highly efficient; as a result of which, eradication seems an uphill task. One of the best ways to recycle weed biomass into a proper nutrient-rich soil conditioner is by composting which will help in agricultural activities. Another way of managing the weed is using the weed biomass as a substrate for anaerobic digestion, which gives biogas, an energy source as the end product. There is more scope for research on the application of Siam weed in dump sites and heavily polluted sites for recovery of heavy metals from the soil, considering its phytoremediation property.

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