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Initiatives and options for utilizing the dreaded weeds lantana (Lantana camara), parthenium (*Parthenium hysterophorus*) and salvinia (*Salviniamolesta)*

by

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Abstract

Lantana (*Lantana camara*), parthenium (*Parthenium hysterophorus*), and salvinia (*Salviniamolesta)* are three of the most dominant and dreaded of the weeds that have invaded and colonized tropical/sub-tripical regions of the world, including India. Whereas lantana and parthenium are terrestrial, salvinia is aquatic. The combined impact of the infestation of land and water-bodies by these weeds has been catastrophic. This paper reviews the initiatives taken so far in finding ways and means of utilizing these weeds as a possible means of controlling their growth, and the viability of the various options.

Keywords: Lantana, parthenium, salvinia, weeds, utilization, medicinals, biofuels

1. Introduction

Lantana (*Lantana camara*), parthenium (*Parthenium hysterophorus*) and salvinia (*Salviniamolesta)* are among the world's most invasive and colonizing of weeds. Of these, lantana and parthenium are exclusively terrestrial (Figures 1 and 2) while salvinia is purely aquatic (Figure 3). Each of these weeds has invaded large areas of landmass or water-bodies in the world's tropical and sub-tropical regions. They also happen to be three of the most commonly encountered weeds in India (Abbasi and Nipaney 1986; 1991; 1993; 1994; Abbasi *et al.*, 1990; 1992a; 1992b; Hussian *et al.*, 2015; 2016a; 2017a; 2018). All the three are very hardy, with exceptionally high rates of reproduction and growth. All are also allelopathic ─ discouraging other vegetation. These attributes, together, make them exceedingly dominant, hence dreaded, of the plant species.

In this paper we have reviewed the attempts made so far to utilize these weeds.

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2. Initiatives to utilize lantana

The studies are summarized in Table 1. It may be seen that attempts have been made to utilize lantana as a source of medicines due to its antoxidant, cytotoxic, antidiarrheal, anticancer, antibacterial, antihelmintic, antiinflammation, and antiobesity activities. It has also been explored as a source of activated carbon, general pesticides, biosorbent, mosquito repellant, biofuel, anticorrosion agent, and a diesel additive. Several authors have also explored its use in biomimetic synthesis of gold, silver, and platinum nanoparticles. Additionally its potential in phytoextraction, phtoremediation, pollutant absorption, heat transfer, and extraction of chemicals such as oleanolic acid has been explored. Attempts have also been made to generate vermicompost/compost from lantana.

Figure 1: Attractive flowers of lantana (top left and right), and scenes of lantana infestation.

However till date no report exists on any of these options having shown potential for economically viable utilization of lantana on a large scale.

Figure 2: Close up of parthenium (top, left) and typical examples of land areas colonized by parthenium.

Figure 3: An adult salvinia plant (top, left) and examples of how salvinia covers water bodies so completely that water goes out of sight.

3. Attempts at utilizing parthenium

The state-of-the art of parthenium utilization is summarized in Table 2.

Parthenium has been used in the production of cellubse, biodegradable poly (3-hydroxybutyrate) or PHB, bioethanol, heat transfer biofluids, biochar, mushrooms, vermicompost, and nanoparticles. The fungus *C.geniculata* growing on it has been tested for plant growth promoting ability. It has been explored as an adsorbent and an antifungal, agent, and as antimycobacterial and an immune-modulator. It has also been tested as a diagnostic marker, and for its antiplasmodial, cytotoxic, and antoxidant activity.

Additionally parthenium has been tested for its potential in phytoremediation and air pollution marking.

But, much like the case of lantana, none of the abovementioned attempts have shown promise of economic viability, and no process exists with which parthenium is being utilized on a large scale.

4. Attempts at the utilization of salvinia

Salvinia being an aquatic plant, that too a free-floating species that requires no soil, has been extensively explored for wastewater treatment/phytoremediation (Table 3). The wastewaters, of which treatment has been attempted using salvinia, include the effluents from coal mines, fish farms, paper mills, palm oil, textile mills, prawn hatcheries, tanneries, and general aquacultural facilities. It has been also explored extensively for removing metals, including non-essential heavy metals cadmium and mercury, from polluted waters.

Abbasi and coworkers have other attempts to benefit from salvinia being a hardy, free floating species, is in exploring it to absorb oil from water. A third avenue of utilization of salvinia, which is not open to lantana and parthenium due to their mammalian toxicity, is possible use as feed. Salvinia had shown some success as feed supplement for duck, fish and ruminants.

It can be said that the deployment of salvinia in wastewater treatment is the only option that has so far been explored for the utilization of any of the three weeds on a large scale. But this option will not contribute to the disposal of salvinia because it does not *consume* salvinia. Once the salvinia plants being used in wastewater treatment systems die, or have to be harvested to prevent overgrowth, they will have to be disposed.

In other words no economically viable option exists as of now with which sizable quantities of any of these three weeds are being consumed.

Summary and conclusion

The reported attempts for the utilization of the terrestrial weeds Lantana (*Lantana camara*), parthenium (*Parthenium hysterophorus*) and free-floating aquatic weed salvinia (*Salviniamolesta)*, have been surveyed catalogued, summarized, and reviewed. It is seen that all the three weeds have been explored for source of medicinals, as biofuel, as a source of other useful chemicals, and in nanoparticle synthesis. Latana and parthenium have also been used as pest repellants, pesticides, and in activated carbon production. On the other hand salvinia has shown much promise as a bioagent for wastewater treatment. It has also been used as a feed-supplement for fish, duck, and mammals. But except for the use of salvinia in sewage treatment, no other option for the utilization of any of the three weeds has been tested on a commercial scale. Even the utilization of salvinia in wastewater treatment does not provide any avenue for the consumption of salvinia as the problem of disposing the spent/harvested weed still remains.

Other uses for which salvinia has been tested are similar to the ones attempted for lantana and ipomoea: source of medicines (especially those with antoxident, antimicrobial, and cytotoxic ability), source of other useful chemicals such as lipids, harmones, and phenolic compounds; source of biofuels, explored the use of salvinia in treating domestic sewage in life-size large-scale units based on their SHEFROL® bioreactor technology (Ponni, 2012; Bhat, 2016; Bhat *et al.*, 2016).

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Table1: A gist of attempts at utilizing lantana (*Lantana camara*)

S.no	*Type of use*	*Plant component used*	*Type of experiment*	*Key findings*	*Reference*
1	Phytochemical,antioxidant and cytotoxic potential	Leaf	The ethyl acetate extract of *L.camara* was investigated for its antioxidant properties by diphenyl-2-picryl-hydrazyl (DPPH) method. Seven fractions were investigated for their antioxidant properties and total phenolic content.	Antioxidant activity of extract of L.camara leaves is directly proportional with the total phenolic content of the extract.	Suryati, 2016
		Leaf and root	Assessment of antioxidant activities of ethanolic extractsof L.camara and L. *montevidensis*.	(i) The ethanolic extracts of leaves exhibited more antioxidant activity than the root extracts. (ii) *L.* camara and *L. montevidensis* could be potentially usedfor the treatment of several diseases due to its ability to act as an antioxidant.	Sousa *et al*., 2015
		Leaf	Assessment of antimicrobial activity and phytochemical screening of L. camara using methanol extract.	*L.*camara extracts showed more antimicrobial activity compared to kanamycinagainst *P. auroginosa*.	Patacsil et al., 2014
		Flowers and leaf	The essential oil of flowers (FLCO) and leaves (LLCO) of L.camara were obtained by hydrodistillation, and analyzed by GC/MS.	(i) Both the oils exhibited antimicrobial activity against *B. cereus* and *B.subtillus*. (ii) Both the oils showed moderate antioxidant activity and this effect were increased by increasing their concentrations.	El Baroty *et al*., 2014
		Seeds	Antimicrobial activities of methanol, chloroform, acetone, petroleum ether and hexane extracts of *L.* camara seed was investigated by using agar well diffusion method. Their activity was tested against four human pathogenic bacteria.	(i) Methanolic extract of L.camarashowed maximum inhibition against *S. aureus*, *P.aeruginosa* and *E. coli*. (ii) It had no inhibitory effect against *P. vulgaris.*	
			Ethanol, methanol, ethyl acetate and water extracts were prepared from dry leaf powder and fresh fruits (both unripe and ripe fruits) to find out its antioxidant activity.	All four extracts of leaf, fruits showed considerable antioxidant effect.	Amutha, 2014
			Total phenolic, flavonoid content, antioxidant and free radical scavenging activities of L. camara were determined using methanol extracts.	L. camara extracts showed a strong correlation between its phenolic content and their antioxidant activities.	
			Assessment of antioxidant, antimicrobial and antifungal activities of		

		Leaf, unripe and ripe fruits	methanol, ethanol and water extracts of L. camara.	*L.* camara extracts were proved to be effective against selected bacterial and fungal strains.	Layavarjitha and Kadamban, 2014
		Leaf	Assessment of antioxidant activity of L. camara by Soxhlet extraction method using ethanol as a solvent.	L.camara showed 19% antioxidant activity.	Kumar *et al.*, 2014
		Leaf	Four extraction solvents including 100% and 80% methanol, ethanol coupled with three extraction techniques (stirring, microwave-assisted stirring and ultrasonic-assisted stirring) were employed to access the antioxidant and antimicrobial activity of *L.* camara	Antioxidant and antimicrobial agents from *L.* camara can be used for nutraceutical and therapeutic applications.	Naz and Bano, 2013
		Not stated	Extraction of bioactive compound from *L. camara* by High-performance liquid chromatography (HPLC) to test its antimicrobial activity.	The study showed antimicrobial activity against *E. coli*, *P. aeruginosa*, *B. subtilis* and *E. fecalis*.	Khan *et al.*, 2013
		Flowers	Chemical constituents representing 97.5% of the essential oil of *L. camara* were identified by GC-MS analysis.	Essential oil of *L. camara* showed antibacterial activities against *S. aureus* and *E. coli*.	Manzoor *et al.*, 2013
		Not stated	Diphenyl-2-picryl-hydrazyl (DPPH) radical, reducing power and nitric oxide radical scavenging assays were carried out to evaluate the antioxidant potential of the methanol, chloroform, hot water and diethyl ether extracts of the roots of *L.camara*.	Methanol extracts of *L.camara* was found to be the most effective compared to other extracts.	Pradeep *et al.*, 2013
		Not stated	Different extraction solvents (80% methanol, 80% ethanol, absolute methanol and absolute ethanol) were assessed for its antioxidant activity of *L.camara*.	L. camara proved to be a rich source of natural antioxidants.	Unnithan *et al.*, 2013
		Root	Assessment of phytochemical characterization and antioxidant activity ofL. camara and L. *montevidensis*.	Both plantsshowed free radical scavenging activity and can be an important source of antioxidant.	Remya *et al.*, 2013

		Leaf and flower Not stated			Anwar *et al*., 2013 Sousa *et al*., 2013
2	Antidiarrheal activity	Stem	Assessment of antidiarrheal activity of the aqueous stem extract of *L. camara* in mice.	*L.camara*, thus provide the scientific basis for the treatment of diarrhea.	Tadesse *et al.*, 2017
3	Adsorptive removal of water pollutants	Leaves and stem	*L. camara* were used to prepare activated carbon by chemical activation method and its lead adoptions potentials were studied.	This is a pioneer study were *L.camara* have been used as a precursor for activated carbon and can be used for adsorptive removal of pollutants.	Saini *et al.*, 2017
4	Anticancer agents	Leaf Not stated Not stated Leaf	Assessment of anticancer activity of *L.camara* using methanol extracts. Identification of a natural anticancer agent from *L. camara*. Minor compounds of L. camara were prepared semi-synthetically in single step by reducing lantadenes A and B under microwave irradiation. Antitumor pentacyclic triterpenoids, lantadene A and B were isolated from L. camara.	*L. camara* showed anticancer potential against HeLa cervixs cancer cells. *L. camara* extract can be used as an anti-breast cancer drug. (i) Minor compounds showed selective cytotoxicity against cancer cells. (ii) Lantadenes A and B have the potential to be developed as anticancer agents. These compounds showed marked cytotoxicity in micromolar range.	Arbiastutie *et al.*, 2017 Han *et al.*, 2015 Kumar *et al*., 2013 Tailor *et al.*, 2013
5	Feedstock for combustion process	Stem	*L. camara* has the potential to be used as a feedstock to generate electricity.	The activation energy calculated using the model free methods and the mean values were105.83, 193.6, 184 and 197.8 kJ/mol.	Havilah *et al.*, 2016

6	Pesticides	Whole plant	Assessment of L. camaraextractsas seed soaking treatment against reniform nematode infesting cowpea.	Cowpea plants were better and reniform nematode, reproduction and populations were reduced in all the treatments compared to control.	Patil *et al.*, 2016
		Leaves	Fumigant toxicity of essential oil extracted by *L. camara* was tested against almond moth.	*L. camara* proved to be an effective pesticide in early/late egg stage, larva and adult stage of almond moth.	Gotyal *et al.*, 2016
		Leaf	Powdered dry leaves of L. camara were used to test their allelopathy effect against root knot nematode.	Significant ($P \leq 0.05$) reduction in dry weight of both *C. olitorius* and *E. colonum* was obtained by using leaf residues in comparison to unwedded control.	EL-Nagdi *et al.*, 2016
			L.camara extracts were tested for their nematicidal activities against root knot nematode.	*L. camara* extracts proved to be the most active and exhibited 80% mortality compared to standard furadan.	
		Leaf and stem		*L. camara* is found to possess larvicidal potency against *A. salina*.	Begum *et al.*, 2015
			Aqueous ethanol extracts (3:1) of *L. camara* were studied for its larvicidal activity.	Essential oils of *L. camara* can be used to control *H. contortus*.	
		Leaves	Assessment of the efficacy of L.camara*'s*essential oils on gastrointestinal nematodes.	Coumaran being a grain protector, also found to be a potent biofumigant.	Udayaprakash *et al*., 2014
			Coumaran a natural bioactive molecule were isolated from L. camara and was tested for pest attack during seed germination.		Macedo *et al.*, 2013
		Not stated	*L.camara* is used for pot treatments to determine its efficacy against nematode infection in chickpea.	*L. camara* extracts can effectively control nematode infection.	
		Leaf	Extracts of L. camara were assessed for its activity against termite infested buildings.	*L.*camara extracts showed 100% termite mortality and thus paves way to overcome synthetic termiticides problems.	Rajashekar *et al.*, 2013
					Rehman *et al.*, 2103
		Flower	Assessment of the efficacy of *L.camara* leaf extracts on mussel scale infection in black pepper.	Extracts of *L. camara* could be used as botanical pesticides for organic farming.	Kaur and Raut, 2013
		Leaf	Crude powders of *L. camara* were evaluated for repellence, anti-	Extracts of *L. camara* could be used for pest management options in	

		Leaf Not stated	feeding and toxicity on adult *P. truncatus*.	smallholder agriculture.	Sreekanth, 2013 Chebet *et al.*, 2013
7	Biosorbent	Fruit	Investigation was done to explore the performance of the acid-treated L.camara as a biosorbent.	*L. camara* extract acts as an effective biosorbent in removing toxic hexavalent chromium.	Nithya *et al.*, 2016
		Not stated	Assessment of *L. camara* in raw (LR) and modified form (LM) for adsorptive removal of two basic dyes.	Modified form of *L. camara* (LM) has considerable potential for removal of RhodamineÂ B (RB) and methylene blue (MB) from aqueous solution.	Banerjee *et al.*, 2016
		Not stated	Mass transfer studies were done to evaluate the rate-limiting step in the adsorption of phenol from aqueous solution onto L. camara.	*L. camara* can be used as a potential adsorbent for the removal of phenol werein the rate-limiting step was found to be film diffusion.	Girish, and Murty., 2016
			Assessment of the maximum adsorption capacity of activated carbon derived from L. camara to remove the hexavalent chromium from aqueous solution.	Highest removal efficiency of the biosorbent was found to be almost 99% under optimal conditions.	
		Fruit	Assessement of L. camara as an adsorbent to remove phenol from aqueous solution.	Maximum adsorptioncapacity was found to be 149.77 mg g^{-1}.	Nithya *et al*., 2015
			Preparation of the activated carbon biosorbents from *L.camara* was carried out by sulphuric acid activation process.	*L.camara* adsorbent is used for the removal of an acidic dye tartrazine from aqueous solutions.	
		Stem	Adsorption of an anthraquinone dye Alizarin Red S onto biosorbent of *L. camara* has been studied on aqueous solutions.	(i) Kinetic studies revealed that the process was quite rapid and more than 90 % of equilibrium capacity was achieved within 80 min. (ii) Thermodynamic studies showed that the Alizarin Red S biosorbent system is spontaneous, exothermic and	Girish, and Murty., 2015
		Not stated			Gautam *et al.*, 2015

		Not stated		favourable in nature.	Gautam *et al.*, 2014
8	Antibacterial	Root bark and flower	Petroleum ether, ethyl acetate, ethanol, and aqueous extracts of *L. camara* were tested against *E. coli*, *S. typhi*, *P. aeruginosa*, *S. aureus*, and *B. subtilis*.	(i) Root bark in ethyl acetate extract showed highest activity against all bacteria. (ii) Flower ethyl acetate extract proved to be significant against *B.subtilis* and *S.typhi*.	Jhariya *et al.*, 2016
			Antibacterial activity of crude methanol extract of *L. camara* was testedagainst *P. emblica*, *P. roxburghii*, *D.salicifolia*and *P. aeruginosa*.	Methanol extract of L. camara proved to be an effective antibacterial agent.	Zulqarnain*et al.*,2015
			Assessment of antibacterial activity of leaf extract (LELC) of *L. camara*.	*L. camara* extract showed antibacterial activity against gram negative bacteria.	Inbaraj *et al.*, 2014
		Not stated	Assessment of essential oils of lantana for its antibacterial activity against 6 strains, using broth dilution method.	Both the leaf and stem oils showed inhibitory activity against *S. aureus*, *S. epidermidis*,*B. subtilis*, *B.dysenteriae*, *B. proteus*, and *E.coli*.	Zhu *et al*., 2013
		Leaf	Assessment of L.camara for its antibacterial potential.	Extracts of *L. camara* may be used to develop functional food and herbal medicines to treat oxidative stress diseases and bacterial infections.	Naqvi *et al.*, 2013
		Leaves, fruits and stems	Dried leaf powders were extracted using a hot-solvent extraction method with eight polar to non-polar solvents and were assessed for its antibacterial activity.	Dichloromethane and methanol leaf extracts of *L. camara* proved to be effective against all bacterial strains.	Dubey and Padhy, 2013
		Flowers and fruits	Assessment of antibacterial activity against gram-positive and gram-negative bacteria using disc diffusion method.	L. camara extractswere active against *E. faecalis*, *S. aureus* and *K.pneumonia*.	Garg *et al*., 2013

		Leaf			
9	Micropropagation and callus induction	Shoot	An efficient technique for the micropropagation and callus induction of *L. camara* was developed.	The produce plants and callus of *L.camara*, can be used as sources for bioactive ingredient.	Veraplakorn, 2016
10	Weed suppression	Leaves	Organic mulch of L. camara, were assessed for its weed control efficiency.	The maximum weed control efficiency of 72% was recorded.	Thankamani *et al.*, 2016
11	Mosquito repellent	Whole plant Leaves	Assessment of *L. camara* extracts against mosquito. Assessment of the repellent activity of creams formulated with methanol crude extract, hexane fraction, and ethyl acetate fractions of *O. gratissimum* and *L. camara* in single and combined actions against female *A. aegypti*.	*L. camara* oils and juices from crushed fresh parts of the plants, or various prepared extracts applied on uncovered body parts serve as mosquito repellent. The combination of *O. gratissimum* and *L. camara* to formulate natural mosquito repellent using small amount of extracts can be an alternative to conventional repellents.	Pavela & Benelli, 2016 Keziah et al., 2015
12	Biofuel	Not stated Not stated	Two coupled kinetic models have been constructed to model laccase mediated delignification of *L. camara*. Assessement of the feasibility of L. camara as a feedstock for biofuels production.	Tessier's model gave better performance in delignification of *L.camara* when compared to Michaelis Menten model. High yields of fermentable sugars from L. camara, even under un-optimized conditions, clearly indicate it's feasibility in the production of alcoholic biofuels.	Gujjala *et al.*, 2016 Borah *et al.*, 2016
13	Enhancing oxidative stability of biodiesel	Leaf	Assessment of *L. camara* extracts for its total phenol, flavonoid, reducing power activity and free radial scavenging capacity using ethanol, methanol, ethyl acetate and chloroform.	Ethanol extract of *L. camara*showed the highest in antioxidant activitiy and also increased the oxidative stability of biodiesel.	Ismail and Ali, 2016
14	Synthesis of nanoparticles	Root	Assessment of antioxidant and cytotoxic potential of gold nanoparticles (AuNPs) synthesized using lantana extract.	Diphenyl-2-picryl-hydrazyl (DPPH) assay, the inhibitory concentration (IC_{50}) was 24.17 and 5.39 µg/ml, and	Ramkumar *et al.*, 2017

				for the cytotoxicity assay IC_{50} was 17.72 and 32.98 µg/ml on human breast cancer cells and Vero cells respectively.	
		Leaf	Evaluation of AgNPs synthesized using *L. camara* on dose–dependent antibacterial and antioxidant potential.	The extract proved to be efficient against *S. aureus*, *E. coli* and *P. aeruginosa*; and toxicity on brine shrimp.	Shriniwas and Subash, 2017
		Flower	To explore the potential of *L. camara* in the fabrication of gold nanoparticles (AuNPs).	This approach is inexpensive, rapid and eco-friendly for industrial scale production of nanoparticles.	Kumar *et al.*, 2016
		Flower	Synthesis of silver nanoparticles (AgNPs) using notorious weed, *L.camara*.	Surface-modified AgNPs could be used effectively in future biotechnological concerns.	Kumar *et al*., 2016
		Leaf	Synthesis of silver nanoparticles (AgNPs) of *L. camara* and to determine its antioxidant activity using Diphenyl-2-picryl-hydrazyl (DPPH) test.	(i) Increase in the concentration of AgNPs increased the DPPH scavenging activity. (ii) AgNPs showed antibacterial activity against gram positive and gram negative strains.	Manjamadha and Muthukumar, 2016
		Leaf	Assessment of *L. camara* for the synthesis of platinum nanoparticles, using ascorbic acid.	The collective action of ascorbic acid and leaf extract reduces the chloroplatinic acid to platinum nanoparticles and can also serves as a stabilizing agent.	Mavukkandy *et al.*, 2016
		Flower, leaf and stem	Assessment of silver nanoparticles (Ag NPs) which is synthesized by reacting aqueous solution of silver nitrate ($AgNO_3$) with *L. camara* extract for its antibacterial activity.	The synthesized AgNPs showed antibacterial activity against *E.coli*, *P.aeruginosa*, *S.aureus* and *B. subtilis* were found to be effective even at lower concentrations.	Rochlani *et al.*, 2016
			Assessment of silver nanoparticles (AgNPs) synthesized using *L.camara* extract for its antibacterial and catalytic activities.	(i) AgNPs exhibited good antibacterial activity when tested against using standard Kirby-Bauer disc diffusion assay. (ii) Catalytic activity on the reduction of methylene blue by *L. camara* was identified using UV-Vis spectrophotometer.	

				The AgNPs proved to be effective against all bacterial strains.	Ajitha *et al.*, 2015
		Leaf	Assessment of *L.camara* mediated silver nanoparticles (AgNPs) with different leaf extract (LE) quantity for its bactericidal activity. Extracts of *L. camara* were used to synthesize the silver nanoparticles (AgNPs) and its antioxidant activity against 1, 1-diphenyl-2- picrylhydrazyl were determined.	Surface modified AgNPs showed higher antioxidant activity than berry extract against 1, 1-diphenyl-2-picrylhydrazyl and could be futher explored in ethno pharmacological field.	
			L.camara extract were used for the synthesis of silver nanoparticles.	Green route synthesized nanoparticles are extremely toxic to multidrug resistant bacteria and have widespread applications in biomedical science.	Ajitha *et al.*, 2015
		Leaf		(i) Transmission electron microscope (TEM) analysis revealed the average size of SNPs were 17 ± 9.5 nm with 5% LE of *L. camara*	Kumar *et al.*, 2015
		Ripened berry	Effect of temperature and leaf extract (LE) concentration of *L. camara* was assessed on the synthesis and size of silver nanoparticles (SNPs).	(ii) Desired size SNPs can be synthesized using these LEs at a particular temperature for its application in the biomedical field	
				Gold nanoparticles (AuNPs) were synthesized by thermal reduction of chloroauric acid ($HAuCl_4$).	Singh *et al.*, 2015
		Leaf	Aqueous extracts of *L. camara* were used as a reducing and stabilizing agent.		
					Kumari *et al.*, 2015
		Leaf			

		Leaf			Sane *et al.*, 2013
15	Insecticide	Leaf, stem and flowers and fruits	Aerial parts of *L. cámara* were evaluated for its insecticidal activities against *C. maculatus*.	Seven different concentrations were studied among which 5.0% dose was highly significant.	Ranjan *et al.*, 2016
		Leaf	Assessment of L. camara extract with petroleum ether compounds for its activity against subterranean termites, *R.flaviceps*.	(i)*L.* camara extract of petroleum ether had a strong repellent effect at higher concentrations. (ii) Although the extract had no toxic effect on termites, its antifeedant activity was significant.	Han *et al.*, 2016
		Leaf	Assessment of L.camara extracts on antifeedant and larvicidal activities of polar and non polar solvents, using leaf disc no-choice method against different stages of *P.xylostella*.	(i) Increasing the concentration resulted in higher deterrence and larval mortality. (ii) Hexane extract of *L.* camara has the potential to serve as an alternate biopesticide for insect pest management.	Thanavendhan and Kennedy, 2016
			Aqueous extracts of lantana were tested for its anti-termitic effect using subterranean termite (*O. wallonensis).*	*L.* camara was observed to be effective termiticide.	
		Not stated	Assessment of *L.* camara extract for its biofumigant potential against housefly.	Biofumigants (Coumaran) of *L.camara* could be an alternative to chemical fumigants against stored grain insect pests.	Vasanthi *et al.*, 2016
		Leaf	Acetonic plant extracts of L.camara, were tested for their insecticidal and repellent effectiveness using saw-toothed grain beetle.	Application of these extracts may be promising in protecting stored date and grains against the attack of *O.surinamensis*.	Rajashekar et al., 2014
			L. camara extracts were prepared by Soxhlet separation by n-hexane, dichloromethane and methanol, evaporated to dryness and kept at 4 °C until toxicity test. Twenty adult gravid females of *T.urticae* were placed on mulberry leaf disc and extracts were	(i)Dichloromethane and n-hexane extracts of *L. camara* flowers repelled	Madkour *et al*, 2013

		Not stated Leaf and flowers Leaf	applied by “no choice and choice bioassay”. Assessment of *L. camara* extracts as larval inhibitor in house flies.	66.04 ± 5.45% and 60.83 ± 3.45% *T. urticae* from the leaf discs. (ii)Dichloromethane, n-hexane and methanol extracts of *L. camara*flowers reduced the oviposition per day rate of *T. urticae* to 42.3, 34.7 and 17.4% when compare to ethanol-treated controls. *L. camara* was a strong repellent for oviposition and showed a significant larvicidal activity in *M. domestica* when compared to *O. basilicum*, *G. jasminoides* and *D. viscose*.	Srimongkolchai et al., 2013 Ahmed *et al*., 2013
16	Bioactive compounds-treats infections and respiratory disease (antimicrobial potential)	Leaf Leaf Leaf Stem	To identify and characterize the main production sites of the biologically active substances in the leaf blades of *L. camara*. Assessment of the effect of different solvents (ethyl acetate, methanol, acetone, and chloroform) on the extraction of phytoconstituents from *L.camara* and their antioxidant and antibacterial activities. Assessment of leaf extract of *L.camara* (LELC), alone and with gentamicin, ceftrioxone using disc diffusion and agar dilution method for its antimicrobial effect. Herbal tincture was developed from *L. camara* at different concentrations of 20%, 40%, alcohol in tincture were tested against standard Iodine (I2).	This helps in gaining knowledge of the sites responsible for the production of substances with ecological and medicinal value (i) The presence of various phytocompounds in the extracts. (ii) Methanol extract had the highest inhibition activity against all the tested microbes. (i) The LELC showed antibacterial effect against NDM1 strain producing bacteria in addition to gram negative bacteria. (ii) Hence LELC has the potential for the development of an ideal and futuristic antimicrobial agent against NDM1 producing organisms.	De Melo Silva *et al.*, 2016 Swamy *et al.*, 2015 Inbaraj *et al.*, 2015

			Assessment of antimicrobial properties of lantana in the presence of active alkenes and long chain fatty acid molecules.	(i) *L. camara* tincture was non-inferior to iodine. (ii) Concentrated extracts of *L.camara* revealed its accelerated healing and better anti-microbial competency so that it can be developed for clinical practice.	Kumar *et al*., 2015
		Flowers		*L.camara* proved to be effective against S. aureus, *P. mirabilis, P. aeruginosa, B. cereus* and *E. coli.*	Vaibhav *et al*., 2013
17	Fungicide	Leaf	Lantana extracts were used as bio-agents to manage downy mildew of pea.	*L. camara* extracts proved to be effective in managing mildew disease.	Patil *et al*., 2017
		Leaf	Assement of *L. camara* extracts for its antifungal activity against *C. gloeosporioides*.	*L. camara* extracts can serve as an alternative means of post-harvest mango anthracnose disease management.	Deressa *et al.*, 2015
		Not stated	Assessment of *L. camara* extract for its antifungal activity using the agar well diffusion method.	*L. camara* extracts proved to be effective fungicide against *C.albicans* and *F. udum.*	Sharanappa & Vidyasagar, 2015
		Leaf	To evaluate the efficacy of *P.lilacinus* in combination with five concentration of *L. camara* crude aqueous leaf extract against *M.incognita* on tomato.	(i) *L. camara* extract alone significantly ($P \leq 0.05$) inhibited root galling and egg production compared with their respective control. (ii) Application of *P. lilacinus* twice in combination with 0.80g mL^{-1} of *L. camara* extract was the most effective treatment.	Udo *et al.*, 2014
			Assessment of lantana essential oils on the phytopathogens (rice pathogens).	L.camara essential oils proved to be efficient against *B. oryzae* and *G.oryzae*.	
		Not stated	Investigating methods of preparing verbascoside-rich plant extracts from *L. javanica* and *L.camara*.	*L. camara* is an excellent source of verbascoside.	Knaak *et al*., 2013

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		Leaf			Oyourou *et al.*, 2013
18	Production of plant growth promoting actinomycetes	Root (rhizosphere)	Lantana root rhizosphere was used to isolate actinomycetes.	The isolated actinomycetes serves as plant growth promoter and can also be used as biofertilizers.	Damam *et al.*, 2016
19	Metal phytoremediation potential	Root and shoot Fruit	Assessment of theextracts of L. camara for their metal uptake potential. Different concentrations of lead were used to contaminate a characterized soil with empty fruit bunch and spent mushroom compost as amendments with L. camara alongwith controls.	(i) L. camara showed translocation from root to shoot for most of the metals except Mn and Pb. (ii) L. camara can be used as a phytoextractor of metal for fly ash dumpsite reclamation. *L.* camara is a potential indicator plant for phytoremediation.	Pandey *et al.*, 2016 Alaribe and Agamuthu, 2015
20	Medicinal use	Not stated Not stated Leaf	Assessment of *L. camara* for its anthelmintic activity. To evaluate the wound healing property of L.camara in diabetic rats. To formulate and evaluate the herbal gel containing L.camara leaf extract. Assessment of L.camara, for itsantioxidant and anti-tyrosinase activities.	Lantana plant extracts had promising effects against *F.hepatica.* Topical application of ethanolic extract of L.camara showed dose dependent wound healing activity in diabetic rats. Better stability was observed by the formulation containing L. camara when applied on animal model (rats no skin irritation was noticed). L.camara proved to be an effective antioxidant and the extracts can be used as skincare products.	Alvarez-Mercado *et al.*, 2015 Shetty and Amuthan *et al*., 2014 Pawar and Shamkuwar, 2013 Priyadharsini *et al*., 2013

		Not stated			
21	Beneficial in sustenance of the butterflies	Not applicable	L.camara, an invasive plant species, was assessed highlighting its role in maintenance of butterfly diversity.	The existence of *L.* camara in urban gardens and forests may prove beneficial in sustenance of the butterflies.	Mukherjee *et al.*, 2015
22	Organic fertilizer	Leaves	Vermicompost derived solely from a weed such as lantana known to possess plant and animal toxicity, hence was used to assess its impact on the germination and early growth of several plant species.	Billions of tons of phytomass that is generated annually by lantana and other invasives can be gainfully utilized in generating organic fertilizer via vermicomposting.	Hussain *et al.*, 2015
			Composting of lantana biomass was done and changes in chemical characteristics of waste biomass were measured.	Composting can be a potential technology to manage lantana biomass for sustainable land fertility management programs.	Rawat and Suthar, 2014
		Not stated	Assessment of vermicompost derived from lantana on the germination, growth, and yield of a botanical species, has been carried out.	Allelopathic ingredients of lantana seem to have been totally eliminated during the course of its vermicomposting and that lantana vermicompost has the potential to support germination, growth, and fruit yield better than equivalent quantities of inorganic fertilizer.	Karthikeyan *et al*., 2014
		Leaf	Long term effects of lantana residue and fertilizer application were studied on nitrogen (N) fractions in a *T. Hapludalf* under rice-wheat cropping.	(i) After 12 crop cycles, lantana and fertilizer application showed an additive effect on the buildup of different N fractions. (ii) Inclusion of lantana indicated net saving of 33% fertilizers plus higher yields and sustained soil health.	Sharma *et al*., 2014
		Not stated	Vermicomposting trials of L.camara spiked with cow dung in different ratios using *E. fetida*.	Lantana may be a potential source for vermicompost production for sustainable agriculture.	

		Leaf			Suthar and Sharma, 2013
23	Pb phytoextraction	Not stated	Assessment of metal extraction using microcosms combining earthworms (*P.corethrurus*), L.camara and soil spiked with 500 and 1000 mgPbkg^{-1}.	(i) Pb uptake by *L.* camara increased by about 2.5-fold in the presence of earthworms, regardless of the Pb concentration. (ii) Interactions between earthworms and soil microorganisms have a positive effect on Pb-phytoextraction yield.	Jusselme *et al.*, 2015
24	Heat transfer biofluids	Not stated	L. camara were used as model systems to investigate as heat transfer biofluids for their potential application in heat transfer industries.	(i) The thermal conductivity of *L.* camara biofluids was found to be higher than that of various nanoparticles based nanofluids. (ii) *L.* camaracan be used as coolants in heat transfer industries instead of water used in various industries.	Wan *et al.*, 2015
25	Isolation of bioactive chemical	Leaves	Isolation and identification of flavonoid compound from the leaves of lantana.	Compound 1 (Gautin) showed highest antibacterial activity against gram negative bacteria, *E. coli* and highest antifungal activity against *A. niger*.	Patil *et al.*, 2015
26	Antibiotic potential	Leaf and root Leaf	Antibacterial activities of lantana-ethanol extracts alone or in association with aminoglycosides were determined by a micro dilution test. To investigate the anthelmintic activity of L. camara extract using adult earthworm, *P.posthuma*.	*L. camara* extracts in combination with aminoglycosides proved to be effective against bacterial strains. The extract exhibited significant dose dependent anthelmintic activity.	De Sousa *et al.*, 2015 Londhe *et al.*, 2013
27	Corrosion inhibition	Leaves	Corrosion inhibition of mild steel (MS) by aqueous extract of *L.camara* leaves (AELCL) has been studied by gravimetric method at different temperatures.	(i) Inhibition efficiency increases with increase in inhibitor concentration and decreases with increase in temperature within the studied range of concentrations and temperatures. (ii) Maximum inhibition efficiency of 90% was observed with 6% (v/v) concentration of inhibitor at 30°C.	Bhardwaj *et al.*, 2015
28	Radical scavenging properties	Leaves and stem	Methanolic extracts of the leaves and stem of *L. camara* were used for polyphenols, flavoides and their free radical scavenging properties using ascorbic acid as standard antioxidant.	Lantana leaves proved to be beneficial and showed an effective antioxidant activity.	Ali and Elgimabi, 2015

29	Isolation and characterization of oleanolic acid	Root	To isolate oleanolic acid from the roots of L.camara and its chemical characterization by spectroscopic methods.	(i) Oleanolic acid isolated from *L.camara* root yields 0.9 % w/w of the dried powder. (ii) TLC, HPLC and IR spectra of the isolated oleanolic acid showed identical, characteristic signals and absorbance similar to the reference standards.	Narendra and Ameeta, 2014
30	Bioethanol production	Not stated	L. camara has found to be a potential feedstock for ethanol production.	A maximum bioethanol concentration of 6.01 % (v/v) was obtained using the mutated strain of *S. cerevisiae*.	Kuila and Banrejee, 2014
31	Agricultural potential	Not stated	Bioconversion of agriculture wastes like L.camara as a substrate for oyster mushroom cultivation together with wheat straw as a control.	Utilization of the plant biomass for mushroom cultivation could contribute in alleviating ecological impact of invasive weed species and also offers a practical option to mitigating hunger and malnutrition in areas where the invasive weeds became dominant.	Mintesnot *et al.*, 2014
32	Anxiolytic effect	Leaf	To investigate the anxiolytic activity of ursolic acid stearoyl glucoside (UASG) isolated from L.camara leaves using column chromatography.	UASG showed its anxiolytic effect in dose dependent manner.	Kazmi *et al.*, 2013
33	Anti-obesity potential	Not stated	Anti-obesic activity of *L.camara* was studied on progesterone induced models of hyperlipedemia in mice.	(i) Accumulation of fat in areas like inguinal, epididymal, neck etc. was observed. (ii) Ethanobotanical knowledge of medicinal plants is one of the most prominent sources of new drugs and has shown potential results for treatment of obesity.	Gundamaraju *et al.*, 2013

Table 2: A gist of attempts at utilizing parthenium (*Parthenium hysterophorus*)

S.no	*Type of use*	*Plant component used*	*Type of experiment*	*Key findings*	*Reference*
1	Root fungus improves plant growth through phosphate solubilization	Root	Assessment of plant growth promoting ability of *C.geniculata* (fungus) isolated from P. hysterophorus. The abilities of the fungus to solubilize different sources of phosphorus and to produce indole acetic acid (IAA) were also determined.	(i) *C. geniculata*-inoculated pigeon pea plants exhibited superior growth over uninoculated control plants and the fungus solubilized different sources of P in the order of $FePO_4$>$AlPO_4$>$Ca_3(PO_4)_2$. (ii) This enables the use of this fungus as bioinoculant in plant production systems.	Priyadharsini and Muthukumar, 2017
2	Cellulase production	Not stated	Assessment of P. hysterophorus for cellulase production using *T.reesei*, bysolid-state fermentation.	(i) Highest cellulase production was achieved on the 8th day of incubation, at 30 °C, keeping solid-to-liquid ratio to be 1:2. (ii)*T.reesei*grown onP. hysterophorusproved to be effective in cellulose production.	Saini *et al.*, 2017
3	Adsorbent	Not stated	Assessment of P. hysterophorusgenerated activated N-biochar (PH-ANB) as a sorbent for the effective removal of micro-pollutant and ranitidine hydrochloride (RH).	(i) A maximum removal of 99% of RH was achieved at an adsorbent dose of 0.05 g L^{-1}, agitation speed 120 rpm, pH 2, equilibrium time 90 min and temperature 20 °C. (ii) This proves PH-ANB could be an effective adsorbent.	Mondal *et al.*, 2017
		Not stated	Assessment ofP. hysterophorusgenerated chemically modified N-biochar (CMNB) as a potential sorbent for the removal of ibuprofen from contaminated water using NaOH.	(i) Maximum adsorptive removal of ibuprofen by CMNB was found to be more than 99% at adsorbent dose of 20 g L^{-1}, agitation speed 160 rpm, pH 2, initial ibuprofen concentration 20 mg L^{-1}, equilibrium time 120 min and temperature 20°C. (ii) CMNB could be a cost-effective and efficient adsorbent.	Mondal *et al.*, 2016
4	Biochars	Not stated	Assessment ofP. hysterophorusgeneratedbiochar for its physicochemical properties.	(i) Biochar produced at higher temperature had higher water holding capacity and pH, which can be used as a soil amendment. (ii) The biochar produced at 650°C had highest yield in the range of 28.52– 39.9 % by weight.	Narzari *et al.*, 2017
		Not stated	Assessment of P.hysterophorusgenerated biochar on soil and cultivation system (rice and wheat) over a period of one year.	(i) Use of biochar is cost effectivein both rice and wheat cultivation. (ii) Biochar increased the C/N ratio of soil andact as a good conditioner. (iii) Structure as well as the water/nutrient holding capacity of soil was improved owing to the macroporous nature of biochar.	Shafiq, 2016
				With increase in temperature, biochar yield decreases,	

		Not stated	*P.hysterophorus* was charred at different temperature (200-500°C) and residence time (30-120 min) to obtain biochar.	whereas its stability increases.	Kumar et al., 2013
5	Synthesis of biodegradable poly(3-hydroxybuty-rate) (PHB)	Not stated	Synthesis of biodegradable poly (3-hydroxybutyrate) (PHB) polymer from *P.* hysterophorususing sonication.	The PHB content of dry cell mass was 8.1-21.6% w/w, and the PHB yield was 6.85×10^{-3}-36.41×10^{-3}% w/w raw biomass.	Pradhan *et al.*, 2017
6	Anti-fungal and anti-mycobacterial activity	Not stated	Assessment of P. hysterophorusfor its antifungal activity using methanol extract.	Parthenium extracts showed activities between 31.25 and 125µg/mL against several *Candida* strains.	Garza *et al.*, 2017
7	Vermicomposting	Not stated	Assessment of vermicomposting of parthenium mixed with biogas plant slurry in six different combinations for 60 days.	(i) Worm biomass and cocoon production increased in all the vermibins and the best results were shown by 100 % biogas plant slurry than the other combinations. (ii) NPK in the vermicomposts was found to be higher and their C: N ratio was < 20 indicating that parthenium-spiked biogas plant slurry serves as nutrient-rich manure. (i) Parthenium, known to possess a strong negative allelopathy, its vermicompost (VC) manifested none of these attributes. (ii) Rather it enhanced the germination success and can be gainfully utilized in producing organic fertilizer.	Yadav and Garg, 2016
		Leaves	Vermicompost, which had been derived solely by the action of the epigeic earthworm *E. fetida*on parthenium, was tested for its impact on the germination and early growth of *V. radiata*, *A. esculentus* and *C. sativus*.	(i) Vermicompost derived was found to begoodcompared to any other organic manure. (ii) Using the readily available phytomass proved this approach could be economically feasible and eco friendly.	Hussain *et al.*, 2016
		Not stated	Assessment of vermicomposting of P. hysterophorususing *E.fetida.*	(i) The worm growth, biomass gain, cocoon production and antioxidant enzymes were lower in vermibins containing higher concentration of *P.hysterophorus* (without cow dung). (ii)Appropriate mixing of *P.* hysterophorus quantity is an essential factor for the survival of earthworms without causing any harm. *P.* hysterophorus when mixed in appropriate quantities of cow dung can aid worm growth and fecundity.	Yadhav., 2015

		Whole plant	Assessment of vermicomposting of P. hysterophorusonE.*eugeniae*. Nine different concentrations of partheniumand cow dung mixtures were used to assess toxicity.	Spectral results indicate that parthenin toxin and phenols can be eradicated via vermicomposting if mixed with appropriate quantity of cow dung.	Rajiv *et al.*, 2014
		Not stated	Assessment of vermicomposting of*P.* hysterophorus and cow dung mixtures using *E.eugeniae*. Assessment of vermicomposting of*P.* hysterophorus and cowdung mixtures using *E.eugeniae*.		Rajiv *et al.*, 2013
		Not stated	Fourier transform infrared spectroscopy (FT-IR) and Gas chromatography-mass spectroscopy (GCMS) have been used to investigate parthenium mediated vermicompost.		Rajiv *et al.*, 2013
8	Identification of novel P20	Leaf	To investigate which orthologues of P. hysterophorus encodes P20 protein.	(i) Tryptic digest of purified protein revealed the predicted size of the protein is ~20kDa by MALDI-TOF and identification of peptides present in the P20 protein is done by peptide sequence analysis. (ii) A combination of bioinformatics and proteomics approaches led to the identification of novel P20 candidates.	Vemuri, 2016
9	Bioethanol production	Leaf and stem	Assessment P. hysterophorus and itspotential as a source for bioethanol production. Cellulose and hemicellulose of *P.* hysterophorus biomass were converted to sugars using acid and enzymatic hydrolysis. Assessment P. hysterophorus and its potential forsecond generation bioethanol production using	(i) Maximum production of 219.67µL/mL ethanol is found in enzymatically hydrolyzed mixture andthe acid hydrolyzed material, maximum yield was157.57 µL/mL. (iii) Utilization of enzymatic hydrolysis of *P.* hysterophorus derived plant materials would be an eco-friendly approach for bioethanol production. Ethanol obtained on the detoxified lignocellulosic broth under optimal conditions was 0.24, 0.27 and 0.27 g/g biomass.	Gupta *et al.*, 2017

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		Not stated Not stated Not stated Not stated Leaf	three yeast strains namely*T.delbrueckii*, *S. pombe* and *S. cerevisiae*. Assessment P. hysterophorus and its potential forultrasound assisted bioethanol synthesis through simultaneous saccharification and fermentation (SSF). Assessment P. hysterophorus and its potential as a source for bioethanol production. Assessment P. hysterophorus and its potential as a source for bioethanol production. Assessment P. hysterophorus and its potential as a source for bioethanol production using three simple steps namely hydrolysis, saccharification and fermentation.	A 4-fold rise in ethanol and cell mass productivity is seen with ultrasound method compared to conventional methods. (i) Ethanol yield from fermentation of pentose and hexose hydrolyzates was 0.26 g/g raw biomass. (ii) This process also provides a potential solution to effective utilization of the noxious weed such as*P. hysterophorus*. Fermentation of the enzyme hydrolysate was carried out using *S.cerevisiae* at 30°C, 120 rpm for 48 h and an ethanol titer 5.46 g/L was achieved. Researchers can further explore a suitable kinetic model to study the reaction mechanism for hydrolysis of *P. hystrophorus* and optimize different parameters such as temperature, time, acid concentrations and alkali concentrations in order to aid higher yield of ethanol.	Tavva *et al.*, 2016 Singh *et al.*, 2015 Bharadwaja et al., 2015 Singh *et al.*, 2014 Swati *et al.*, 2013
10	Hematological and immune modulator in wistar rats	Leaves	Assessment of *P.hysterophorus*leaf extract on hematological parameters of wistar rats.	(i) *P.hysterophorus*did not support the traditional use of the plant leaf for stimulation of blood production. (ii) However it showed improvement of non-specific immune responses involving phagocytosis and inflammation proving it to be an effective immune modulator.	Vemuri *et al.*, 2016
11	Antimicrobial activity	Whole plant	Assessment of *P.hysterophorus* for its antimicrobial activity using chloroform, methanol, acetone, ethyl acetate, petroleum ether and distilled water. Ciprofloxacin and amphotericin were used as standard antibiotics.	(i) Some of the solvent extracts of the plant showed the highest activity against some pathogenic microorganisms than standard antibiotics used. (ii) The findings support production of new bioactive compounds from invasive weeds.	Kaur *et al*., 2016

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		Stem Leaves Leaves	Assessment of *P.hysterophorus* for its antimicrobial activity using ethanol extract. AssessmentofP. hysterophorus for its antimicrobial activity using agar well diffusion method against *S. aureus, B. subtilis, E. coli, P. aeruginosa, C. albicans* and *S. cerevisiae*. Assessment of*P.hysterophorus*for its antimicrobial activity against clinical isolates of bacterial and fungal cultures using methanol extract.	Antimicrobial activity was observed with *E. coli, A.niger, C. albicans* while, *S. aureus* showed no zone of inhibition. Organic leaves extract of weeds were more effective than aqueous extract. Antimicrobial activity exhibited by the methanol leaf extract has shown significant potential in inhibiting various pathogens.	Krishnaveni *et al.*, 2015 Kaur *et al*., 2016 Krishnavignesh *et al*., 2013
12	Diagnostic markers in medicine	Flower	Assessment of *P.* hysterophorus flower proteins for its IgG purification using phenol extract. The purified allergens were characterized by sodium dodecyl sulfate-polyacrylamide gel electrophoresis.	Several proteins in the range of 18-40kDa could be used as diagnostic markers for patients allergic to *P.* hysterophorus.	Vemuri, 2016
13	Anti-plasmodial activity in medicine	Aerial part and roots Whole plant	Crude extracts from the aerial part and root of *P.* Hysterophorus, were assessed for itsanti-plasmodial activity against *P. berghei* and its citotoxicity against human fibroblast. Assessment of*P. hysterophorus* for its antiplasmodial activity against chloroquine-sensitive and chloroquine-resistant strains of *P. falciparum* grown in human red blood cell.	(i) Lactonerich extract of *P.* hysterophorus aerial part was the most cytotoxic compared to root extract. (ii) The potential of lactone-rich extract from *P.* hysterophorus as a basis for a future anti-malarial phytomedicine. (i) *P. hysterophorus* showed an antiplasmodial activity ofIC50: 2.1 mg/ml against *P. falciparum*. (ii) Thus confirmsthe traditional use of some invasive plants against malaria.	Valdés *et al*., 2016 Singh *et al.*, 2015
14	Pesticide	Not stated Stem, leafand	Assessment of P. hysterophorusand 4 other plants against the growth of *T.castaneum* using ethanol and acetone ectracts. Assessment of *P.hysterophorus*powders against *C. maculatus* on stored chickpea seeds.	P. hysterophorus proved to be most effective inhibitor of egg hatching in *T.castaneum* compared to other plant extracts used for the study. (i)The leaf, inflorescence and stem powder caused 40 - 73.33%, 43.33 - 83.33% and 36.67 - 56.67% adult mortality, respectively.	Khan et al., 2016 Patro and Patro, 2015

		inflorescence		(ii) Highest inhibition rate was 86.16% in leaf powder and lowest of 57.73% in stem powder.	
15	Medicinal use (gastric ulcer)	Not stated Leaf, root, flower and stem Leaf Flower and root	Assessment of *P. hysterophorus* extracts against*H. pylori* growth and colonization-related factors. Assessment of *P. hysterophorus*for its antibacterial activity usingsolvents such ashexane, benzene, and chloroform. Assessment of *P. hysterophorus*for its cytotoxic and antioxidant potential. Assessment of *P. hysterophorus*extracted using Soxhlet apparatus for its antioxidant potential.	Dichloromethane–methanol extracts possess the highest effect, with 70% maximal inhibition of *H. pylori*, growth and colonization at 1 mg/ml. *P.* hysterophorusextracts revealed considerable antibacterial, antioxidant, lipo-protective, antihemolytic, and anticancer potential. Phytochemicals present in *P.* hysterophorus leaf have considerable potential as cytotoxic and antioxidant agents with low to moderate anti-HIV activity. Phytochemicals present in *P.hysterophorus* extracts have considerable antioxidant potential as well as lipo-protective activity against membrane damage.	Espinosa-Rivero *et al*., 2015 Kumar *et al*., 2014 Kumar *et al*., 2013 Kumar *et al*., 2013
16	Heat transfer biofluids	Not stated	*P. hysterophorus*were used as model systems to investigate as heat transfer biofluids for their potential application in heat transfer industries.	(i) The thermal conductivity of *P. hysterophorus* biofluids was found to be higher than that of various nanoparticles based nanofluids. (ii) *P. hysterophorus*can be used as coolants in heat transfer industries instead of water used in various industries.	Wan *et al*., 2015
17	Enhanced enzymatic hydrolysis	Not stated	Assessment of P. hysterophorus to establish the mechanism of the ultrasound-induced enhancement of enzymatic hydrolysis.	Trends in kinetic and physiological parameters of *Hexachlorocyclohexane-1*(HCH-1) model reveal that sonication enhances enzyme/substrate affinity and reaction velocity of hydrolysis.	Singh *et al*., 2015
18	Synthesis of nanoparticles	Leaf Not stated	Assessment of *P.hysterophorus*leaf extract for itssize-dependent antibacterial activities using the synthesizedsilver (Ag) nanoparticles. Assessment of *P.hysterophorus*as reducing and capping agent for degradation of Reactive Red 31 using the synthesized titanium dioxide (TiO_2) nanoparticles.	*P. hysterophorus* leaf extract capped 20±2nm Ag nanoparticles (7.5g/ml) shows statistically significant antibacterial activity against gram negative *P. aeruginosa* and gram positive *S.aureus*. Biogenic TiO_2 nanomaterial acts as a good photocatalyst for the degradation of textile dye Reactive Red 31.	Anwar *et al*., 2015 Khan and Fulekar, 2015

		Root	Assessment of P.hysterophorus against *C.quinquefasciatus* using the synthesized silver nanoparticles from aqueous root extract.	The synthesized silver nanoparticlesshowed moderate larvicidal effects against *C.quinquefasciatus* compared to commercial pesticides.	Mondal *et al.*, 2014
		Leaf	Assessment of P.hysterophorus for the synthesis of zinc oxide nanoparticles.	(i) To synthesize zinc oxide nanoparticles from *P. hysterophorus* by inexpensive, ecofriendly and simple method. (ii) To explore its size-dependent antifungal activity against plant pathogens.	Rajiv *et al.*, 2013
19	Biofuel	Not stated	Assessment of P.hysterophorus for biofuel production.	*P.* hysterophorus has same potential for being the feedstock for biofuels as that of other conventional agro- and forest residues.	Singh *et al.*, 2014
20	Substrtae for mushroom cultivation	Whole plant	Assessment ofP. hysterophorusas a substrate for oyster mushroom cultivation together with wheat straw as a control.	*P.ostreatus* grown on *P.* hysterophorus had a biological efficiency of 83.87% and production rate is 3.13 which is significant at $p<0.01$.	Mintesnot *et al.*, 2014
21	Seed priming	Leaf	Assessment of P.hysterophorusfor its effect on rice seedling using methanol leaf extracts (10:100 w/v).	P.hysterophorus extracts increased germination rate and germination percentage as compare to control.	Ashfaq et al., 2014
22	Allelopathy- use in weed suppression	Whole plant	Assessment of P. hysterophorus for controlling weeds in wheat along with reduced doses of phenoxaprop-p-ethyl and bromoxinil+MCPA.	Weed density was encouragingly suppressed (compared to control) when the allelopathic plant water extracts were used in combination with lower doses of herbicides.	Khan and Afridi, 2014
23	Antibacterial activity	Leaf	Assessment of *P.* hysterophorus extracts for its antibacterial activity using benzene, ether and chloroform.	It strongly indicates antibacterial potential of *P.* hysterophorus extracts against bacterial pathogens of rice crop.	Ashfaq *et al.*, 2013
		Not stated	Assessment of *P.* hysterophorus forits antibacterial activitiy against,*P. aeruginosa*, *M. luteus* and *B. cereus*using disc diffusion method.	(i) Methanol was the best solution for extracting the effective antibacterial materials from P. hysterophorus compared with standard drug, ciprofloxacin. (ii) This shows the importance of producing new bioactivity compounds having antibacterial activity.	Malarkodi and Manoharan, 2013
24	Germination and seedling growth	Leaf, stem and root	Assessment of P. hysterophorusfor its allelopathic potential in relation to the germination and seedling growth of two crops namely*R.sativus* and *B. juncea*.	(i)*P.hysterophorus* extracts (100%, 50%, 25% and 5%) inhibited seed germination as well as hypocotyl and radicle lengths of two crop species and the inhibitory effect increased with increasing extract concentration. (ii) The order of this inhibitory effect was leaf > stem > root on two target species.	Hu *et al.*, 2013
25	Phytoremediation	Root and shoot	Assessment of P. hysterophorusfor its heavy metal accumulation potential.	(i)P. hysterophorusfound to have an enrichment coefficient of >1, which reflects its high metal accumulation potential.	Kumar *et al.*, 2013

	potential			(ii) Itcanbe used for the phytoremediation and restoration of land contaminated toxic metals.	
26	Antifungal activity	Not stated	Assessment of P. hysterophorus for its antifungal activities using extracts of ethanol, chloroform, methanol, acetone, ethyl acetate, hexane, petroleum ether and aqueous.	Methanol was the best solution for extracting the effective antifungal materials from the P. hysterophorus compared with standard drug, ketoconazole.	Malarkodi and Manoharan, 2013
27	Isolation, identification and screening of endophytic Streptomyces	Leaf and root	Isolation identification and screening of 42 endophytic streptomycetes strains from parthenium roots and leaves.	(i) Crude extracts of 12 strains of S*treptomycetes* spp, exhibited significant antimicrobial activity against multi drug resistant nosocomial pathogens including *Pseudomonas*, *Enterobacter*, *Bacillus*, *E. coli*, *S. aureus* and *C. albicans* (ii) This provides an insight into an untapped endophytic environment yet to be explored.	Tanvir *et al.*, 2013
		Not stated	Assessment of P. hysterophorusfor the presence of polyketide synthases type I(PKS-I gene) in endophytic streptomyces.	(i) Molecular screening revealed that the presence of PKSI gene with a PCR amplification products of size ~300 bps, ~320 bps and ~700 bps. (ii) This provides an insight into an unexplored environment which if further investigated may lead to a new source of antimicrobial agents.	Tanvir *et al.*, 2013
28	Air pollution tolerance index and antioxidant activity	Leaf	Assessment of *P.* hysterophorusfor itssecondary metabolites mediated antioxidant activity and air pollution tolerance index.	*P.* hysterophorus was found to be a tolerant species to pollution, its high flavonoid content might be playing a major role in imparting antioxidant potential.	Krishnaveni, 2013

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Table: 3: Attempts at utilization of *Salvinia molesta*

S.no	*Type of use*	*Plant component used*	*Type of experiment*	*Key findings*	*Reference*
1	Phytoremediation	Whole plant	Assessment of *S.molesta* in detoxifying coal mine effluent	i) *S. molesta*removed Pb -96.96% > Ni - 97.01% > Cu- 96.77% > Zn- 96.38% > Mn- 96.22% > Fe- 94.12% > Cr- 92.85% > Cd- 80.99% in 10 days. ii) Impact of coal mine exposure on chlorophyll content showed a significant decrease of 42.49% from the control.	Lakra *et al*.,2017
		Whole plant	Assessment of *S.molesta* in treating fish farm wastewater	i) *S.molesta* significantly removed 95% phosphate, and other parameters such as ammonia, turbidity and total suspended solids were within the standards in just 2 days.	Ng *et al*., 2017
		Whole plant	Assessment of salvinia for the removal of color and chemical oxygen demand (COD) from pulp and paper mill effluent	Salvinia plan efficiently removed 49.72% color and 100% COD from the effluent.	Ahmad *et al* .,2017
		Whole plant	Assessment of S.*molesta* in treating palm oil mill effluent	*S. molesta* achieved 95% phosphate removal efficiency from the wastewater it also increased the biomass, which is superior in biochemical content that has its economic value.	Ng *et al*.,2017
		Not stated	Assessment of S.*molesta* in removal of heavy metals from industrial effluent.	i) Heavy metals contents (less than 10 ppm) as within the permissible levels, except for chromium and lead. ii) *S.molesta* can grow healthy with the accumulation of these metals.	Ranjitha *et al* .,2016
		Root	Assessment of salvinia in heavy metals removal	Salvinia removed 102% of Fe and all the parameters such as BOD, COD, DO, pH, turbidity, oil and greese, nitrate and nitrite were within permissible limits.	Razak *et al.*, 2013
		Roots	Assessment of *S.molesta* for heavy metal remediation.	Salvinia could successfully be used for phytoremediation of mining tin tailings	Ashraf *et al* 2012
		Whole plant	Assessment of *S.molesta* for heavy metal remediation.	Successfully be used for phytoremediation of mining tin tailings	Ashraf *et al* ., 2011
		Not stated	Assessment of *S.molesta* for the removal of polar micro contaminants.	Salvinia contributes to the elimination capacity of micro contaminants in wetlands through biodegradation and uptake processes.	Matamoros *et al.*, 2012
		Root	Assessment of *S.molesta* and their potential as the heavy metals removal in root zone via	Salvinia removed 102% of Fe and the contaminant is successfully absorbed by the root in order to stabilize the industrial wastewater	Abdul and Sulaiman, 2014

			phytogreen system.		
2	Wastewater treatment	Whole plant	Assessment of *S.molesta* to treat textile effluent	Salvinia plant significantly reduce the values of COD, BOD_5 and ADMI by 76%, 82% and 81% considering initial values 1185, 1440 mg/L and 950 units, respectively.	Chandanshive *et al*.,2016
		Not stated	Assessment of *S.molesta* to treat effluents from Nile tilapia culture ponds	*S. molesta* 72.1% of total phosphorus and 42.7% of total nitrogen indicating that the treated effluents may be reused in the aquaculture activity.	Henry and Camargo, 2006
		Not stated	Assessment of the nutritive value of *S. molesta* used in a Nile tilapia waste treatment and the species biomass potential uses.	i) Aerial part of salvinia observed 64.2% crude protein, 9.1% soluble carbohydrates, 18.7 mg.g-1 dry mass and lipids 4.5 %. ii)*S. molesta* aerial biomass have nutritive values with potential use for ruminant feeding or as ration ingredients.	Henry and Monteiro, 2002
		Not stated	Assessment of *S.molesta* to treat the wastewater	When nutrient concentrations are high, it can be predicted that 5.11 g N m -2 day -1 and 0.85 g P m -2 day -1 can be removed at a water temperature of 25℃, but only 1.1 g N m -2 day -1 and 0.18 g P m -2 day -1 at 12℃. This has a direct bearing on the design and costing of waste-water treatment ponds using salvinia for excess nutrient removal.	Toerien *et al*.,1983
		Not satated	Assessment of *S.molesta* for the removal of chromium from tannery effluents by phytoremediation	Salvinia have great potential to remove chromium, which ranges from 36-99% in 10 days.	Mishra *et al.*, 2010
		Root	Assessment of*S. molesta* to treat the effluent of a giant river prawn	*S.molesta* wetland suspended total inorganic nitrogen 19.8%, total Kjeldahl nitrogen (TKN) 30.9%, P-orthophosphate (PO4-P) 23.8% and efficient in treating pond effluent due to the root surface which forms an extensive area favorable to retention and adsorption of debris and absorption of nutrients.	Henares *et al*.,2014
		Leaves	Assessment of *S. molesta* to treat wastewaters containing zinc(II), and the subsequent conversion of the harvested weed into energy (biogas),	The uptake of zinc by the weed was very efficient - 50% zinc being removed within 15 days and 90% within 30 days of growth. The average gas yield from uncatalyzed salvinia is 30.4 L/kg (fresh weight). The 35-day average yield in presence of zinc (I1) works out to be 40.3 L/kg (fresh weight) thus 33% enhancement in yield in the presence of zinc (I1).	Abbasi and Nipaney, 1985

			Assessment of *S.molesta* as a potential for the removal of heavy metals in highly polluted water	Salvinia efficiently removed nitrogen, phosphorus and zinc	Finlayson *et al.*,1984
		Not stated	Assessment of *S.molesta* for the removal of chromium from wastewater by phytoremediation	Chromium removal from spiked solutions ranged from 40-99% in 7 days.	Shiny *et al.*, 2004
		Not stated	Assessment of *S.molesta* for the absorption of cadmium from water	Salvinia showed ultrastructural changes at 0.1 ppm andcan be considered as an indicator of Cd in water	Gupta and Devi, 1995
		Not stated	Assessment of *S.molesta* for the removal of chromium and nickel from wastewater	The rate of percentage removal of metal ions was observed to be 56-96 and 18-72% after the first 2 and 14 days and the nickel and cadmium-enriched solution the biomass growth of Salvinia was high	Srivastav *et al.*,1994
		Not stated	Assessment of *S.molesta* for treating aquaculture effluent	i)N and P concentrations were significantly higher ($P<0.05$) in the inflow (mean of 0.66 mg L–1 and 233.6 mg L–1, respectively) than in the outflow of the tanks (mean of 0.38 mg L–1 and 174.7 mg L–1, respectively) ii)*S. molesta*, biomass gain was 135.2 and 143.1 g DM.m2, in the higher and lower concentrations, respectively	Henares and Camargo, 2014.
3	Oil absorption	Leaves and hairy roots	Assessment of *S.molesta* for oil absorption capacity	i) Salvinia are super hydrophobic and super oleophilic, and selectively absorb oil while repelling water. ii) *S.molesta* improved artificial bioinspired oil absorbents.	Zeiger *et al.*,2016

		Not stated	Assessment of *S.molesta* for the sorption of oils onto the dry biomass and the results were compared with commercial oil sorbent, peat Sorb, a processed peat.	i)The *S.molesta* biomass was a better sorbent for oil than Peat Sorb (for a crude oil, 4.8 against 2.7 g of oil sorbed per g of biomass). ii)Main factors that control the sorption process were the hydrophobicity of the biomass, particle size, the chemico-physical composition of the plant and the sorbate, and the capillary suction displayed by the plant biomass	Ribeiro *et al.*,2000
		Not stated	Assessment of *S.molesta* for the oil removal and retention capabilities of the biomass sorbents which included kapok fiber, cattail fiber, Salvinia sp.,	i)The mass of oil sorbed for salvnia was greater than 70% i) Oil selectivity (hydrophobic properties) and physical characteristics of the sorbents are the two main factors that influence the oil sorption capability.	Khan *et al.*,2004
4	Synthesize of nano particle	Leaves	Assessment of *S.molesta* in synthesis of silver nanoparticles (AgNPs), which is tested for its antimicrobial efficacy	The synthesized AgNPs were found to be an effective antibacterial agent against both gram positive and gram negative bacteria.	Verma *et al.*,2016
		Whole plant	Assessment of *S.molesta* in synthesis of gold nanoparticles (AuNPs).	The synthesized AgNPs were found to be stable and used as a bioagent.	Abbasi *et al* 2016
5	Antioxidant activity	Leaves	Assessment of *S.molesta* for its antioxidant activity using extracts of aqueous, ethanol, methanol, chloroform, and petroleum ether by the diphenyl-2-picrylhydrazyl assay	i) Among the five different solvents, the maximum antioxidant activity of *S. molesta* was found in the ethanolic extract 90.3% followed by other solvents ii) *S. molesta* possess significant antioxidant activity and used as a potent therapeutic agent	Nithya *et al.*,2016
6	Source of forage	Leaves	Assessmemt of *S.molesta* for its potential as a source of feed stuff influencing meat characteristics in ducks	*S. molesta* can be used as a dietary source of fatty acids for the production of healthy duck meat.	Dwiloka *et al.*, 2015
		Not stated	Assessment of *S.molesta* and its potential as a source of local duck feed	15% *S. molesta* to the local duck ration resulted in an increase in the body weight and feed conversion ratio , as well as increasing the income over feed cost by approximately IDR 2,468.65.	Santoso and Setiadi, 2016
		Not stated	Assessment of *S.molesta* as a feed for the herbivorous fish, tilapia (*Oreochromis niloticus Linneus*)	After 23 days the fish growth was (7.3 g per fish). Salvinia could be used as a feed supplement or ingredient in tilapia diets.	King *et al.*,2004
		Leaves	Assessment of *S.molesta* as a source of forage for ruminants.	Salvinia contain crude ash (17.3% in DM) and of lignin (13.7%) and tannins (0.93%) as a potential feed source for ruminants	Moozhiyil and Pallauf, 1986
7	Antibacterial activity	Leaves	Assessment of *S.molesta* for itsantibacterial	*S. moletsa* can be used as complete therapeutic agents since it	Nithya*et al* 2015

			activity *using* leaf extract of 20 ml ethanol (75%), acetone, chloroform, aqueous and petroleum ether	possess significant activities ranging from antibacterial to immunomodulator.	
8	Extraction of cytotoxic compounds	Not stated	Assessment of *S.molesta* for its cytotoxic potential using ethanol extract.	Bioactive compounds from salvinia, particularly salviniol have promising potential in the drug development for cancer.	Li *et al*., 2013
9	Source of bioactive compound	Leaves	Assessment of *S.molesta* for its phytochemical potential using extracts of petroleum ether, ethyl acetate, methanol, chloroform, acetone, benzene and water.	*S.molesta* extracts show the presence of many bioactive compounds after extensive investigation.	Mithraja *et al*., 2011
11	Lipid extraction	Not stated	Assessment of *S.molesta* for lipid extraction using methanol:chloroform in 2:1 ratio.	A lipid yield of 92.4% was obtained at the optimized conditions of temperature (85°C), solvent to biomass ratio (20:1), and time (137 min), whereas a predicted lipid yield of 93.5 % with regression model.	Mubarak *et al*.,2016
12	Determination of heavy metals	Leaves	Assessment of *S.molesta*for heavy metals accumulation.	i) Heavy metal content (less than 10ppm) was within the permissible levels, except cadmium and lead. ii) *S. molesta* can grow healthy with the accumulation of these metals and used for the production of biodiesel.	Sandhyasree *et al*., 2015
		Not stated	Assessment of *S.molesta* for heavy metals accumulation and tolerance in plants growing on ex-mining area.	The plant species identified could be useful for revegetation and erosion control in metals-contaminated ex-mining sites.	Ashraf *et al* ., 2010
13	Source of plant harmones	Not stated	Assessment of *S.molesta* for its mineral content.	Leachate collected on days 7 and 14 had biological activity indicating that auxin-like compounds were released from *S. molesta* upon decomposition.	Arthur *et al*., 2007
		Whole plant	Assessment of *S.molesta* for detecting plant harmones using the soybean callus bioassay	Cytokinin-like activity was detected in the culture medium in which the ferns had been growing and activity co-eluted with the same cytokinins found in the plant material.	Stirk and Van, 2003
14	Removal of heavy metals	Not stated	Assessment of *S.molesta* for removal of	Salvinia plant showed to possess different affinity for the	Espinoza *et al*.,2005

			trace metals in river water under laboratory conditions.	incorporation of the metals in its biomass and metal abatement in dilute wastewaters.	
		Whole plant	Assessment of *S. molesta*, as green leaf manure in rice (Oryza sativa L.) nursery.	*S. molesta* obtained grain yield 51.9 g/ha to nursery.	Raju and Gangwar, 2004
15	Isolation of phenolic compound	Whole plant	Assessment of *S. molesta* to isolated the phenolic compound	i)Two glycosides, 60 -O-(3,4-dihydroxy benzoyl)-b-D-glucopyranosyl ester (1), and 4-O-b-D-glucopyranoside-3-hydroxy methyl benzoate (2), along with five known compounds methyl benzoate (3), hypogallic acid (4), caffeic acid (5), paeoniflorin (6) and pikuroside (7) were isolated for the first time from a fresh water fern *S.molesta*. ii)These compounds showed a potent antioxidant radical scavenging activity in a non-physiological assay	Choudhary *et al.*,2008
16	Biofuel	Whole plant	Assessment of *S.molesta* for biogas production	*S.molesta* can be successful used as biofuel production	Abbasi and Nipaney, 1984
		Whole plant	Assessment of *S.molesta* for the production of methane	*S.molesta* yield energy (methane) of the order of 108 Kcal ha-[1] year-[1].	Abbasi *et al.*,1990
		Whole plant	Assessment of *S.molesta* as bioagent for treating wastewaters	i)Salvinia can weed can grow upto 4-5 days in 100 ppm of nickel and cadmium ii)Anaerobic digestion of the weed spiked with low concentrations (1.18 mg L-1) of each of the metals revealed that all metalsenhance biogas yield except chromium, The stimulatory effect followed the trend Cu (51%) >Mo (45%) >Zn (30%) >Hg (24.4%) = Cd (23.8%) > Ni (14%)	Abbasi and Nipaney, 1994.
17	Nanoscale biomimetics	Leaves	Assessment of *S.molesta* for enhancing air retention	The results indicate that the air-retaining property was greatly enhanced using the salvinia structure	Yang *et al.*,2013
		Not stated	Assessment of *S.molesta* for long-term air-retention	The complex elastic eggbeater-shaped hairs with a coating of SU-8 photoresist can support a droplet water of 1 ml. This work offered a new simple method to mimic the properties of *S.molesta* surface.	Tengfei *et al.*,2016
		Fern hair	Assessment of *S.molesta* to mimic the air trapping ability	A novel methodology for the fabrication of microstructures mimics the water-pinning and air-trapping ability of *S. molesta*. Water contact angle, water roll angle and adhesive force of the new microstructure and water fern are study.	Hunt and Bhushan, 2011.

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