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Invasive Weed Threats in India and Their Ecosafe Management

R. K. Ghosh*, Anannya Ghosh, Dibyendu Mondal

Department of Agronomy, Faculty of Agriculture, Bidhan Chandra Krishi Viswavidyalaya (BCKV), India

***Corresponding author:** R. K. Ghosh, Department of Agronomy, Bidhan Chandra Krishi Viswavidyalaya (BCKV), Mohanpur, 741252, Nadia, West Bengal, India. Tel: +919433145340; Email: drajr1956@gmail.com

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Abstract

The Ecosphere is badly tormenting for Food, Oil, Nutrient, Fuel, Ecological and Health [FONFEH] securities because of global warming and population increasing. The Best Management Practice [BMP] of resources with more biological management in system agriculture is the prime solution to overcome this problem. Pest causes 33 % production losses nationally. The major pest weed alone cause more than 10 % production loss. Because of climate change impacts the weed pest biodiversity is changing. *Ambrosia, Conyza, Cynoglossum, Cyperus, Eichhornia, Elatine, Oryza* (wild), *Parthenium, Phalaris, Polypogon, Viola* etc. alien anthophytes are invaded in newer regions and dispersed in many crop fields around the globe and their menace is gradually arrogance forcing urgent Ecosafe management to protect environment for increasing productivity as well as food and oil security. Utilization of these alien invasive weeds as compost making, green manuring, bio pesticides, breeding, biogas, pharmaceutical etc. may be one of the Ecosafe managements besides governing by Ecosafe organic chemicals in most waste and fallow lands. This will also generate employment opportunities in rural areas. There is also an urgent need of training and awareness through agri-skill development program me of all categories for proper management of these alien invasive weed pests.

Keywords: Ecosafe Chemicals; Invasive Weed Diversity; Management Through Utilization

Introduction

The World is desolation due to Food, Oil, Nutrient, Fuel, Ecological and Health [FONFEH] securities. The food demand is expected to be doubled by 2050 because of steady population increasing in spite of production environment and natural resources are continuously shrinking and deteriorating. Food crisis has aggravated further because of climate change and diversion of arable lands to urbanization, industrialization and for producing bio-fuel. About 30% global emissions leading to climate change are attributed to agricultural activities, including land-use changes. There are projections that demand for food grains in India would increase to 345 mt in 2030. Hence in the next 15 years, production of food grains needs to be increased at the rate of around 5 mt annually, which a challenge to agriculturists. In such situation the Best Management Practice [BMP] with what farmers have is the greatest alternative methodology. The production losses due to pests is 33 % and the major pest weed plant alone causes [10.9 &11.5] % national & global production losses [1]. This is further vexing due to threats from invasive alien weed pest. Climate change and the import of food grains & seeds are the two major causes for the invasion of weeds in India. Management of these invasive weed pests are, therefore, urgently needed for global and national food and oil security.

Invasive Weeds Biodiversity

The biodiversity changing in weed pest due to climate change is the key factor for invasion of many alien weeds in newer ecosystem [2]. The invasive weed flora common in many countries are Ambrosia in Mediterranean region; *Elatine* in Japan, Polypogon in China, *Phalaris* in Mexico, *Parthenium* in Mexico, *Conyza* in America, *Oryza rufipogon* in Malaysia, *Cyperus rotundus* in India etc.

In past only a few weed species like *Eichhornia crassipes*, in India was invaded because of its' beautiful flower but thereafter in most of the SAARC countries, the pitiable quarantine system further intensifying this problem as the alien invasive plants are continuously invading through importing of seed and grains. These are pernicious and spreading rapidly. One of the classical examples is *Parthenium hysterophorus* commonly observed in the roadside since last 3-4 decades is now encroaching in crop fields.

The following invasive weed flora [Table 1] is documented of quarantine significance to India according to special provisions for quarantine weeds [class 3(12)] & schedule VIII of plant quarantine order 2005 [till 2016].

1. *Allium vineale* L.	19. *Eichhornia crassipes*
2. *Ambrosia maritime* L.	20. *Froelichia floridana* (Nutt) Moq
3. *Ambrosia psilostachya* D.C.	21. *Helianthus californicus* DC.
4. *Ambrosia trifida* L.	22. *Helianthus ciliaris* DC.
5. *Apera spica-venti* (L.) P. Beauv.	23. *Heliotropium amplexicaule* Vahl.
6. *Bromus rigidus* Roth.	24. *Leersia japonica* Honda. Ex. Honda
7. *Bromus secalinus* L.	25. *Matricaria perforatum* Merat.
8. *Cenchrus tribuloides* L.	26. *Polygonum cuspidatum* Sieb. & Zucc.
9. *Centaurea diffusa* Lam.	27. *Parthenium hysterophorus* L.
10. *Centaurea maculosa* Lam.	28. *Proboscidea louisianica* (P.Mill.) Thellung.
11. *Centaurea solstitialis* L.	29. *Polypogon monspeliensis* L.
12. *Chicorium pumilum* Jacq.	30. *Salsola vermiculata* L.
13. *Chicorium spinosum* L.	31. *Senecio jacobaea* L.
14. *Cordia curassavica* Jacq. *Roemer & Schultes*	32. *Solanum carolinense* L.
15. *Cuscuta australis* R. Br.	33. *Striga hermonthica* (Del) enth
16. *Cynoglossum officinale* L.	34. *Thesium australa* R. Br.
17. *Cynoglossum germinacum*	35. *Thesium humile* Vahl.
18. *Echinochloa cruz* -pavonis (Kunth)	36. *Viola arvensis*

Table 1: Invasive Weed Pests Documented by Plant Quarantine in India.

Survey and Surveillance of Invasive weed

The National Invasive Weed Surveillance (NIWS) Program me under Department of Agriculture & Cooperation, Ministry of Agriculture, government of India was launched in India through the Directorate of Weed Science Research (DWSR), Indian Council of Agricultural Research (ICAR) during 2008-10. In West Bengal, BCKV NIWS Centre was recognized by ICAR by awarding "Recognition Award (2010) to Principle Investigator Prof. R.K. Ghosh" for noticing five Invasive weeds verified by Botanical Survey of India, Kolkata and identifying some other invasive weeds (Table 2 and Figure 1) under this NIWS program me (Final Report 2008-10, NIWS, BCKV Centre). BCKV Centre made this survey in ten south Bengal districts (Burdwan, Hooghly, Howrah, Maldah, Murshidabad, Nadia, North & South 24 Paragnas and Purba & Paschim Medinipur) besides maintaining an 'In house trial 'of the collected wheat seeds from various FCI go downs, ration dealers and the consumers during 2008-10. An invasive weed museum (Figure 2) was also established at BCKV farm to document and acquaint these invasive & pernicious weeds to the farmers, scientists, students and common people.

Identification Institute	**Name of the invasive plants**	**Family**	**Site of collection**
The Botanical Survey of India (BSI), Kolkata dated 5th March, 2010	1. *Solanum Incanum* L 2.*Cynoglossum lanceolatum* 3. *Dianthus armeria* L.	Solanaceae Boraginaceae Caryophyllaceae	Nadia Maldah Purba Medinipur
The Botanical Survey of India (BSI), Kolkata dated 13th July, 2010	*4.Polypogon monspeliensis* L. *5. Jatropha multifida* L.	Poaceae Euphorbiaceae	On station trial, BCKV Purba Medinipur

Table 2: Invasive Weed pests at Gangetic alluvial plains in India recorded during survey of NIWS Program me 2008-10by BCKV Center and Identified by BSI, Kolkata.

West Bengal	Name of Important Invasive Weed pests
Aerobic	*Allium vineale, Cyperushalpan, Desmodium triflorum, Dianthus armeria, Elatine triandra, Euphorbia heleoscopia, Euphorbia heterophylla, Lindernia* (Gratiola) *tenuifolia, Phalaris minor, Polypogon monspeliensis, Polygonum plebium, Tithonia rotundifolia, Trichodesma indicum*
Anaerobic	*Alternanthera philoxeroides, Aneilema vaginata, Cardenthera triflora, Cyperus serotinus, Cyperus polystachyos, Eichhornia crassipes, Eleocharis congesta, Eriocaulon sieboldtianum, Hyptis suaveolens, Oryza rufipogon*
Non-crop, Roadside and Wasteland	*Acanthus ilicifolius*, *Cleome rutidosperma*, *Cleome speciosa, Cynoglossum lanceolatum*, *Hibiscus subdarifa*, *Jatropha multifida*, *Parthenium hysterophorus, Pergularia daemia*, *Rouvolfia tetraphylla, Solanum incanum, Solanum viarum*, *Solanum indisanum, Solanum diphyllum*

Important Major Invasive Weed Pests Recorded in West Bengal in NIWS Program me 2008-10.

Figure 1: Important Invasive Weed Flora Identified During NIWS Program me.

Figure 2: Invasive weed Museum at BCKV farm.

Since 2008 research has been conducting to find out the new invasive weeds through survey, study of invasive weed ecology & biology and their Ecosafe management through utilization and chemically by Ecosafe organic chemical herbicides. All these researches were conducted at on station (Viswavidyalaya farm, Kalyani) and some at on farm (nearby villages of Viswavidyalaya campus).

In House Trial

From the wheat seed samples collected from different FCI go downs, ration dealers and consumer house the in-house trial was done during 2008-09 at Viswavidyalaya farm. The ICAR experts visited the in-house trial at BCKV during 2009. The results (Table 3) showed that *Phalaris minor* was found in the wheat samples of FCI go down and from consumer samples of Nadia, Murshidabad and Maldah district, *Polypogon monspeliensis* was also found only from wheat sample of FCI go down, Nadia. *Polygonum plebium was* found in the consumer wheat samples of both Purba and Paschim Medinipur. *Dianthus armeria* was found in ration dealer wheat samples from Hooghly and consumer samples of Howrah. *Trichodesma indicum* was found in FCI go down sample of both South and North 24 Paragnas.

Parthenium hysterophorus was found in all wheat samples of all surveyed districts. Only one each invasive weed plant *Jatropha multifida* was found at Nandi gram ADA office in the district of Purba Menipur while *Cynoglossum lanceolatum* in Government farm, Maldah. Only a plant of *Solanum incanum* was observed at the roadside of Kalyani University administrative building, Nadia (NIWS Final Report, BCKV Center, 2008-10).

The *Solanum carolinense* is found in Southern India during 2009 (Final NIWS Report, Bangalore & Tamil Nadu Centre, 2008-10). *Eriocaulon sieboldtianum* was observed at bank of the river Ganga at Hooghly district during the RAWE program me of UG students, BCKV.

Name of Weed	Nadia	Maldah	Murshidabad	Purba Medinipur	Paschim Medinipur	Howrah	24-Parga nas (S)	24-Parganas (N)	Hooghly
Phalaris minor	10.14	4.68	5.15	0	0	0	0	0	0
Polypogon monspeliensis	1.67	0	0	0	0	0	0	0	0
Melilotus alba	6.24	2.79	1.33	0	16.24	4.78	10.46	3.75	0
Polygonum plebium	0	0	0	1.67	3.75	0	0	0	0
Oldenlandia corymbosa	6.08	8.12	2.19	12.19	8.12	10.15	7.19	9.15	11.1
Gnaphalium indicum	2.03	6.08	1.33	0	0	0	0	0	5.4
Dianthus armeria	0	0	0	0	0	2.67	0	0	1.33
Sonchus arvensis	10.15	8.12	10.15	0	0	3.78	3.6	1.47	1.8
Trichodesma indicum	0	0	0	0	0	0	1.67	1.33	0
Nicotiana plumbaginifolia	4.07	0	6.08	16.24	4.07	0	7.17	0	1.8
Stellaria media	2.03	4.07	10.15	10.15	6.08	12.19	0	0	8.07
Chicorium intybus	0	8.12	0	6.08	4.07	6.08	0	0	0
Phyllanthus niruri	2.57	0	6.08	0	8.12	0	8.12	0	0
Chenopodium album	5	0	0	3.6	5.4	3.6	8.36	0	14.18

Chenopodium album	1.8	2.03	5	3.6	3.6	10.8	5	2.03	4.07
Physalis minima	5.4	4.07	8.12	0	0	0	4.07	4.07	0
Cenchrus spp.	6.08	0	0	0	0	0	8.12	6.08	2.03
Total no. of weed	60.7	45.29	52.93	49.86	55.79	46.6	55.91	24.14	49.78
Wheat plants	10	9	10.8	5.4	9	16.2	14.4	9	3.6

Table3: District wise weed population m^{-2} (from collected wheat samples).

Research on Invasive Weeds Biology and Management

Parthenium hysterophorous is locally known as Congress grass, White top, Bunogajor. *Parthenium (*having 17 species) may be confused with annual ragweed (*Ambrosia artemisiifolia*), perennial ragweed (*Ambrosia psilostachya*), burr ragweed (*Ambrosia confertiflora*) and lacy ragweed (*Ambrosia tenuifolia*). However, after flowering it can be distinguished from all these species by its ribbed stems and by white flower-heads (i.e. capitula).

The flea banes (*Conyza bonariensis*, *Conyza Canadensis* and *Conyza sumatrensis*) are also reasonably similar, but do not have highly dissected leaves or ribbed stems and their seeds are topped with a ring i.e. Pappus of whitish hairs. *Parthenium* was first found at Pune, India in 1955 and in 1975 at Dankuni, West Bengal. It has been termed 'National weed' since 2005-06. It is a shrub and completing three life cycles (February - May; June - September and October -January of which the former two has profuse growth but the later one has lesser growth) in a year. The plant mainly propagates by seeds. One plant contains 15,000-25,000 seeds which are very light and easily disperse by air and water. It grows well in moist condition but can't tolerate water stagnation. The pollen Alleopathy, a rare phenomenon of inhibiting germination of pollen of other species in their respective stigma shown by *Parthenium* pollen may result in loss of yield of crops. *Parthenium* is causing health hazards to human and animals. It is reported for outburst of the diseases like tomato leaf curl, bud necrosis of groundnut and sunflower, stem necrosis of groundnut, powdery mildew, collar rot, leaf spot, milly bug and rust of various crops. Recently, *Parthenium* has been responsible for outburst of bud necrosis of groundnut in Andhra Pradesh and some parts of Karnataka.

In India, it is estimated to lower the yield of field crops by 40% and forage crops by 90% in severely infested areas. In Australia its damage is put at16 million dollars per annum from pasture and crops. Pollen grains of *Parthenium* are reported to inhibit fruit set in tomato, brinjal, beans, capsicum and maize [3-4]. The biology study of *Parthenium hyterophorus* [5] at West Bengal revealed that it grows initially horizontally (not allow to germinate other plants) and thereafter vertically 3-5 ft with more than 15,000 very light seeds / plant. The density in roadside is more 40 m^{-2} (mean from 10 sites) in comparison to cropped area 4.4 m^{-2}, field bunds 10.9 m^{-2} and field channels 7.8 m^{-2}. It has allele chemicals Sesquiterpene lactone (Parthenin, Hymenin, and Ambrosin etc.) and phenol and flowers particularly showed some allergy to animals. Thus, it should be managed before flowering. Research proved that this alien weed could be managed by utilizing as compost [6], green manure [7], and making bio herbicides [8]. *Parthenium* is also controlled by Ecosafe organic chemical Glyphosate + Oxyfluorfen mixture @ 2 $_g$ / lit water at pre - flowering stage.

Oryza rufipogon [9] is normally taller than *Oryza sativa,* having numerous awned grain per panicle that drops during maturity (also known as Jharadhan). The scourge is commonly known by different names in various Asian countries, *viz.* Kha Nok (Thiland), Sharei (Korea), Jhoradhan (Bangladesh), Lua Lon (Vietnam), Padiangin (Malaysia) or Akamai (Japan), etc. The biology studies of the *Oryza rufipogon (*Ph.D. Thesis project work, Swapan Kumar Barman, BCKV 2013) revealed that it is almost phenol typically alike cultivated rice. If the infestation rate of a crop is 35% or more the average yield losses is to the tune of 60%. Only one plant of was first observed & identified in West Bengal at BCKV Research Farm, Kalyani during October 2007 (reported and published in APWSS Newsletter Vol. 1 No. 1 2008). The plant height is maximum 118 and minimum 55 cm with an average of 86.5 cm; average no. of tillers / plant 56.5; no. of panicles / plant 52.5; maximum panicle length 25 cm and minimum 17 cm with an average 21 cm; the awn length 3-7 cm; no. of spikelets / panicle 9; no. of spikes / spikelet on an average 19; the test weight0.975 g and normally152 day's duration in kharif season. The grain setting of *Oryza rufipogon* in Gangetic inceptisol was found only during June sowing. It is mainly found during rainy season. Initially it is very difficult to identify with cultivated paddy. It can be grown even in water stagnant situation thus suitable for breeding purpose. This weed plant is controlled effectively by utilizing as compost.

Elatine triandra, locally called Chotanunia, is a dicotyledonous broadleaf annual, stem 3-15 cm long, dichotomous, branching; prostate, leaves lance late, opposite with short

petiole and stipules and small flowers at axils. Moisture helps to propagate easily both by seed and plant parts. This weed is generally reddish purple in color, succulent and has soft and short internodes. It has been first observed on 2002 at village Kantabelia of district Nadia in West Bengal. *Elatine* is now invaded in many areas of all south Bengal districts because of its rapid propagation by any parts ofPlant

Ambrosia psilostachya DC. (Family - Asteraceae**),** is commonly known as Western Ragweed or Cuman Ragweed. This annual invasive weed is noticed on road sides in Pura villages of Turuvekere taluk, Tumkur District, Karnataka (about 4 km from Muniyur) during 2013 only. It invaded probably through transportation of soil. This plant looks like *Ambrosia trifida.* It generally prefers moist soil, found in all type of soil and in all habitats. Fruiting and flowering occurs during August-October. It propagates and dispersed primarily by root and seed. It is one of the most dangerous weeds in the world.

Trichodesma indicum [Family - Elatinaceae], is generally found in upland and aerobic situation. Commonly known as'Chatpati' as after maturity the seeds when anyone keeps in their hand jump little. Whole plant at young stage very soft, later mature gradually becomes hard. Looks like *Bergia carpensis* and found in Viswavidyalaya farm, Kalyani during 2009-10 in wheat field of NIWS poly house trial.

Polypogon monspeliensis L. Desf **[**Family -Poaceae (Gramineae)], an annual grass mostly found in crop fields and bunds. The inflorescence is looking like Imperata cylindrical but color is blackish- brownish. Invaded from China and found in Viswavidyalaya farm, Kalyani during 2009-10 in wheat field of NIWS poly house trial. Now it is observed in many dry tracts of India.

Management Through Utilization of Invasive Weed

(As Compost, Green Manure, Bio Herbicides, and Herbal Medicine etc)

Compost Making

All the invasive weeds like other weeds are suitable for making compost at initial stage. For using invasive weeds in Vermicompost at first chopped the weed plants into small pieces and spread the material on the ground to a thickness of 10 cm layer. Over this spread *Trichoderma viridi* and spray urea at 0.5% solution (Generally 5 kg urea per ton of weed material). This sequence of layers is repeated up to a meter high and finally plastering should be done by with mud or clay soil. Keep the moisture level at 50-60%. After two weeks, a thorough mixing must be given. The compost will be ready for field application after 40-45 days. It is a good source of nutrient and helps to maintain soil properties through aggregate formation.

At DWR, ICAR, M.P and BCKV, West Bengal. Attempt was made to utilize *Parthenium* by making compost. As *Parthenium* is now invaded entire India the best possible way to manage it by making compost. The procedure of *Parthenium* Compost preparation is as follows [6]

- Make a pit of 3 ft depth (four layers each having 9" depth) x6 ft width x 10 ft length. It should be in open and shady upland place. Cover the base surface and side walls of the pit by stone chips or make soil surface compact to protect the absorption of compost nutrients by the soil surface by using lime.
- Use 40 kg dry soil and 30 $_{kg}$ well decomposed dry FYM / Vermicompost in each layer. Collect young *Parthenium* plants from nearby areas and spread 50 $_{kg}$ on the surface of the pit in each of 4 layers of this pit. The allelochemical `*Parthenin*' acts as a growth regulator.
- Sprinkle 500 $_{g}$ Urea or 3 kg Rock phosphate over this for each time and spray 10 lit of water on the surface of each layer.
- Add *Tricho derma viridi* @ 50$_{g}$ in each layer and Repeat this type of biomass layer till 4 layers.
- Cover the pit with soil, dung and husk making a 1- 1.5 ft dome shape and keep it for 4-5 months.
- For packaging in bags sieve the final well decomposed compost with 2 cm x 2 cm mesh. The compost is ready for use. Testing of this compost was made in field crops and found good results.

Following same process utilization of *Oryza rufipogon* along with the field crop weeds may also be possible by making 'Field side Compost'. In such case the compost pit may be varied in size according to number of weeds or available space in any ecosystem. The weeds present in the fallow land may also be utilized for making compost. The research data showed the dry weight of 234.86 g m^{-2} was available from fallow or wasteland weed (mean of 10 locations).

Preparation of *Parthenium* compost.

Application of 3-5 t ha^{-1} of this eco-friendly balanced "*Parthenium* compost' or "Field side compost" in the crop, vegetables or Orchards showed no harmful effects not only in soil and succeeding crops but also no resurgence after application in the field. It is less costly than the traditional FYM, oil cakes or even from the Vermicompost (Table 4). Recently attempt has been taken to improve the quality of compost making from various weed floras. The *'Eichhoparth* Compost*'* (mixture of *Eichhornia crassipes* and *Parthenium hysterophorus* 50:50 ratio) is also more nutrient rich and suitable for utilizing both these invasive weeds. This will create employment opportunities in the rural areas. Some field experiments were also conducted at the University research farm to find the efficacy of these composts and the results are promising for sustainable soil health improvement as well as lowering the inorganic fertilizer dose and keeping the productivity a sustainable increase in all crops grown in sequence.

Name of the compost	Nitrogen %	Phosphorus %	Potash %
Vermicompost	1.61	0.68	1.31
FYM	0.45	0.3	0.54
***Parthenium* Compost (DWR, ICAR)**	1.05	0.84	1.11
***Parthenium* Compost (BCKV)**	1.21	0.89	1.34

Table 4: NPK content of *Parthenium*, FYM and Vermi - compost.

Green Manure

Young non-flowered *Parthenium* plant could be used as green manure to enrich the soil health and improving crop productivity. Research experiments conducted at BCKV, West Bengal, India [7] revealed that in major three crop sequences CS_1 - black gram (summer) - transplanted paddy (kharif) - onion (Rabi); CS_2-sesame (summer) - transplanted paddy (kharif) - Bengal gram (Rabi) and CS_3- okra (summer) - transplanted paddy (kharif) - rapeseed (Rabi), the nutrient level N_1(recommended dose of fertilizer+ green manuring with young non- flowered *Parthenium hyterophorus*) under CS_1 recorded maximum rice equivalent yield in all the three seasons 2.99 t ha^{-1} in summer; 5.45 t ha^{-1} in *kharif* and 16.21 t ha^{-1} in Rabi showing N_1CS_1 recorded maximum benefit : cost ratio in all the three seasons. The two-year productivity data under three nutrient levels showed that the highest average productivity of 54.54 $_{kg}$ ha^{-1} day^{-1} was observed in N_1 treatment in case of all the crop sequences. Thus, utilization of biomass as green manure might have the potential to improve crop productivity. A similar finding was also recorded at Karnataka, India in rice ecosystem. The soil micro flora revealed that continues use of *Parthenium* as GM with recommended NPK is beneficial for soil health as well as advantage on total biological yield. The effect of treatments on the population of Bacteria (CFUX10^{6} g^{-1}) of soil was presented in Table 5.

Treatments	2008-09						2009-10					
	Summer		Kharif		Rabi		Summer		Kharif		Rabi	
	Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final
N1CS1	37	90.33	92.33	103	105.33	128.6	132.3	142.6	146.3	164.3	166.7	181
N1CS1	37.67	83.67	85.67	96.33	98.67	122	125.7	136	139.7	157.7	160	174
N1CS1	37.33	80	82	92.67	95	118.3	122	132.3	136	154	156.3	171
N1CS2	36	91.33	93.33	104	106.33	129.6	133.3	143.6	147.3	165.3	167.7	182
N1CS2	37	83.67	85.67	96.33	98.67	122	125.7	136	139.7	157.7	160	174
N1CS2	35	79.33	81.33	92	94.33	117.6	121.3	131.6	135.3	153.3	155.7	170
N1CS3	38.67	89.67	91.67	102.3	104.67	128	131.7	142	145.7	163.7	166	180
N1CS3	38	84	86	96.67	99	122.3	126	136.3	140	158	160.3	175
N1CS3	38.33	81.33	83.33	94	96.33	119.6	123.3	133.6	137.3	155.3	157.7	172
S.Em(+)	0.941	0.348	0.185	0.521	0.289	0.153	0.257	0.398	0.218	0.352	0.419	0.39
CD (5%)	NS	1.043	0.555	1.562	0.866	0.459	0.77	1.193	0.653	1.055	1.256	1.16

Table 5: Effect of Treatments on the Population of Bacteria ($CFU_X 10^6 G^{-1}$) In Experimental Soil.

Bio Herbicides

Raw or aqueous extracts of many invasive weeds in their young stage are common and useful as bio pesticides [10]. For methanol extracts the procedure of bio herbicide preparation with the *Calotropis gigantean* and *Parthenium hysterophorus* was based on the Sox let's procedure. The solid materials are extracted by repeated washing (percolation) with an organic solvent, usually hexane, methane or petroleum ether, etc. under reflux in special glassware. Dry *Calotropis* and *Parthenium* powder is placed into a porous cellulose thimble. The cartridge is placed in an extraction chamber, which is suspended over a flask containing the solvent and below a condenser. The flask is heated and the solvent evaporates and moves up into the condenser, where it cools enough to become a liquid that seeps into the extraction chamber containing the *Calotropis* and *Parthenium* powder sample.

The extraction chamber is designed so that when the solvent surrounding the sample exceeds a certain level it overflows and trickles down into the boiling flask. At the end of the extraction process, which lasts a few hours, the flask containing the solvent is removed along with the *Calotropis* and *Parthenium* extract. Finally, the solvent in the flask evaporates leaving the plant materials extract below. Solvent extracted plant materials powder uses one or more organic to remove the active ingredient and other ingredients of the plant materials powder. Adding surfactant (nonionic) e.g. Tween- 80, Tween- 20, S -145 etc., organic solvents; emulsifier; filler and adjuvant the final spray solution was prepared and this was used to spray in the crop field [11].

Plant extracts with allelochemicals (Table 6) from some invasive weeds containing different allelochemicals like phenols, acid etc. are using as non-selective herbicide. Similarly, fatty acids like pelargonic acids (succinic, lactic or glycolic acid) are using to control annual pests; essential oils use as non-selective contact herbicide to control many weed pests. Many research experiments have been conducting in this aspect in India [12, 8], Australia [13], Japan [14-15], China [16] and many other countries. One of the interesting research findings at Japan that some native rice cultivars contain allelochemicals (Momilactones) which can able to suppress the weed species *Echinochloa* or invasive weed *Oryza rufipogon*. At BCKV, West Bengal since 2001 many experiments were conducted in various ecosystem (anaerobic and aerobic) with different doses(5-100 ml/ liter water) and results are satisfactory with PE application adding surfactant while in recent years 100 ml/ liter water dose showed more efficacy (Table 7). Moreover, in anaerobic ecosystem these botanical herbicides proved better in comparison to aerobic ecosystem. This may be due to presence of phenolic compounds that acts more in sufficient moist soil. It has been further observed that these botanical herbicides can be mixed with synthetic organic herbicides and the results showed this mixture proved synergistic effect in some cases. Therefore, as PE application in zero or minimal tillage (conservation agriculture) managing weeds these mixtures may be more suitable rather than only non-selective contact synthetic organic herbicides.

Plant	Allelochemicals	Action
Ageratum conyzoides/ haustonianum (Gandhali)	Chromoneme derivative precocens	Anti allelo tropic i.e. prevent JH synthesis
Andropogon aciculatus (Chorkanta)	Essential oil - repellent	The oil effective against mosquito
Argemone mexicana (Sialkanta)	Sanguinarine and 11-Oxotriacontanoic acid	Poison - Blindness
Artemisia absinthium (Common rag weed)	Absinthium, a dimeric Sesquiterpene ethanol extracts	Antifeedant activity against insects leaf roller
Artemisia capillaries (Rag weed)	Capillin	Fungal infections
Calotropis gigantean /procera(Akanda)	Calotropin and Mudarine	Controlled most small grassy weeds; Pesticide effects
Blumea lacera (Bon mula) + *Chrysanthemum richilari* (Chandramallika)	Pyrithrum (I & II) and Cinerin (I & II) [same action as Pipernyl Butoxide]	Pest control & against *Meloidogyne* spp after decomposition
Cyperus rotundus (Mutha)	Valencene, Noolkatone	Oil for incense; Pesticide effects
Echino chloacolona (Janglidhan)	Cumaric acid, Apegenin Benzoxazinoids	Potential used for monocot grassy weed control
Lantana camera (Lantana)	Lantradene -A	Jaundice to animal; Weed control, Pesticides effect
Ocimum basilicum / suave (Bon tulsi)	Essential Oil / Leaves	Pesticides effect
Oryza sativa (wild)	Momilactone B	Control grassy weeds like *Echinochloa* spp.
Parthenium hysterophorus (Bon gajar, Sadatupi)	Sesquiterpene lactones & Phenols	Control small grassy weeds; Skin disease
Sorghum halepense (Johnson grass)	High prussic acid**;** Sorgoleone	Suppress the weed growth, Poison to animal
Tephrosia purpurea (Ban neel)	Hildecarpan, a Pterocarpan and Rotenoides & Rotenone	Antifeedant against legume pod borer / Lepidopteran
Xanthium strumarium (Cocklebur)	Carboxy atractyloside	Plant inhibiting effects

Table 6: Allelochemicals activities of some Invasive weed plants (Botanicals) Name of plant.

Year	Research	Conducted by
2001-03	Pilot Trial - Raw extracts with *Calotropis gigantean* in vacant land	Prof. R.K. Ghosh
2003-15	Pilot Trial –Raw and aqueous extracts of some promising weed and plant species in UG & PG practical's	Prof. R.K .Ghosh
2003-05	PhD Experiment on Groundnut & Soybean - Raw extracts *Calotropis* & *Eucalyptus* leaf	Dr. S.K. Ghosh and Prof. R.K. Ghosh
2004-05	Pilot trial on Chili - Aqueous extract mixture of *Parthenium hysterophorus* + *Calotropis procera* + *Tectona grandis*	Prof. R.K. Ghosh
2005-07	PG Experiment on SRI – *Parthenium hysterophorus* raw extracts	Mr. Anadi Bhanja and Prof. R.K. Ghosh

2007-08	PG Experiment on SRI- *Parthenium hysterophorus* raw extracts	Ms. Lanunola Tudzir and Prof. R.K. Ghosh
2008-09	PH. D Experiment on SRI- Raw extracts mixture *Calotropis* & *Parthenium*	Mr. Loknath Sharma and Prof. R.K. Ghosh
2010-12	Ph.D. Experiment on Sesame, Black & Green gram - Raw and Aqueous Extracts of *Ageratum conyzoides*, *Blumea lacera*, *Physalis* minima, *Ocimum tenuiflorum* and *Amaranth us tricolor*	Dr. D. Nongmaithem and Prof. R.K. Ghosh
2009-12	Experiment on SRI, Wheat and laboratory testing and making formulation in Adhoc Project RKVY- Raw, Aqueous & Methanol Extracts of *Parthenium*, *Calotropis* and *Tectona grandis* and their mixtures	Prof. R.K. Kole and Prof. R.K. Ghosh
2010-12	Ph.D. Experiment on SRI - Raw, Aqueous & Methanol Extracts of *Parthenium*, *Calotropis* and *Tectona grandis* and their mixtures	Dr. P.K. Jana and Prof. R.K. Ghosh
2011-14	Ph.D. Experiment on SRI - Aqueous extracts of mixture of *Parthenium*, *Calotropis* and *Tectona grandis* and Aqueous extracts *Bambusa vulgaris*	Dr. S. Sentharagai and Prof. R.K. Ghosh
2011-14	On Farm Trials under Adhoc Project "SRI" sponsored by SDTT, Mumbai at 8 districts of WB. Raw Extracts of *Parthenium*	Prof. R.K. Ghosh (Principal Investigator)
2012-13	PG Experiment on *Arachyis hypogea* (Groundnut)-Aqueous extracts of *Echino chloacolona*, *Cyperus difformis*, *Blume alacera*, *Ageratum conyzoides*, *Cucumis sativa* and *Bambus avulgaris*	Mr. Abisekh Labor and Prof. R.K. Ghosh
2015-16	PG Experiment on SRI Rice- PE Mixture of Botanical + Synthetic chemicals & varied doses	Mr. Chandan Karmakar, Mr. Bharath G. N. Deeps and Prof. R.K. Ghosh
2016-17	Ph.D. Experiment on conservation agriculture crop Potato, Mustard and Lentil - PE Mixture of Botanical + Synthetic chemicals (Continuing)	Dibyendu Mondal, Anannya Ghosh, Prof. P. Bandopadhyay and Prof. R.K. Ghosh

Table7: List of Research Experiments Conducted at BCKV on Sole and Mixture of Botanicals.

The important research findings on transplanted SRI weed management during summer 2010 and2011 by applying botanical herbicides as Raw Extract (RE), Raw Leaf Extract (RLE), Aqueous Extract(AE) and Methanol Extract (ME) revealed that all botanicals treatments (9 Treatments) on an average recorded 28 % yield advantage (Table 8) over Weedy Check (WC).

Treatments	**Weed biomass m-2 At 25 DAA**		**Grain yield (t ha-1)**	**Increase over WC (%)**	**Straw yield (t ha-1)**
	Monocot	Dicot			
T1- Un weeded check	5.58	6.43	4.18		5.33
T2- Mechanical weeding 15 at DAT fb HW at 25 DAT	2.94	5.09	6.23	49	7.24
T3- *Parthenium* AE	3.17	5.21	4.98	19	6.33
T4- *Calotropis* AE	3.35	6.46	5.22	24	6.17
T5- *Tectona* AE	3.02	6.38	5.2	24	6.33
T6- *Parthenium* ME	3.32	4.93	5.4	29	6.31
T7- *Calotropis* ME	3.07	6.2	5.33	27	6.45
T8- *Tectona* ME	2.38	4.95	5.63	35	6.96
T9- *Parthenium* RLE	2.92	6.58	5.37	28	6.27
T10- *Calotropis* RLE	2.45	5.31	5.01	20	6.51
T11- *Parthenium* + *Calotropis* RLE	2.27	4.88	6.01	44	6.95
T12- *Pretilachlor* 50 EC	3.43	2.19	5.74	37	6.82

CD at 5 %	1.21	2.27	1.33	31	1.76

Table 8: Effect of Botanical Plant Extracts on the Weed Biomass and Paddy Grain and Straw Yield (Pooled Data for Two Years Summer 2010 And 2011).

Similarly, in another experiment during 2010-11 the botanical treatments showed a better weed management than the untreated control with an average of 7.8-72.7% higher productivity in cultivated crops *Sesamum indicum, Vigna radiata* and *Vigna mungo* experimented at this Viswavidyalaya (Table 9). No phyto toxicity was observed among the crop species from any of the botanicals used. The soil micro flora population was also recorded to be greater in botanicals treated plots than herbicide treated plots [17]. Working with *Echino chloacolona* extract [18] also found similar results at south India.

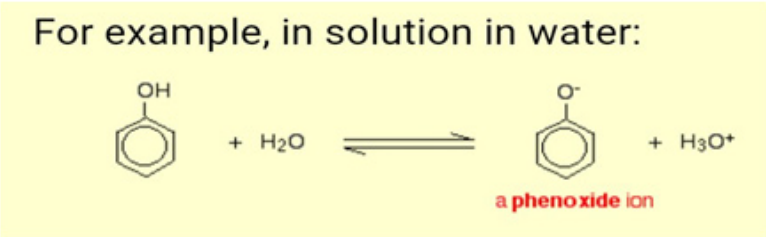
Treatments	Sesamum	Green gram	Black gram
T1-Hand Weeding at 20 DAS	54.38	50.00	72.72
T2 - 5% (w/v) *Ageratum conyzoides* extract	22.80	24.30	9.09
T3 - 5% (w/v) *Blumea lacera* extract	24.56	19.23	7.79
T4 -5% (w/v) *Ocimum sanctum* extract	29.82	25.96	22.07
T5 -5 %(w/v) *Physalis minima* extract	24.56	24.03	15.58
T6 -5% (w/v) *Amaranth us tricolor* extract	26.31	25.00	10.38
T7 -Quizalofop-p-ethyl @50 $_g$ ha^{-1} at 20 DAS	45.61	32.69	70.12
T8 -Fenoxaprop-p-ethyl @30 $_g$ ha^{-1} at 20 DAS	40.35	29.80	64.93

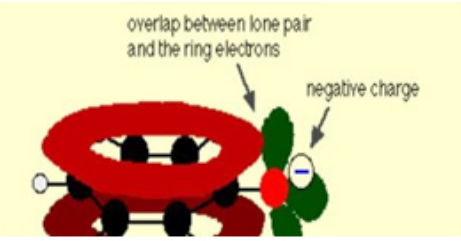
Table 9: Percentage of Yield Increase over Control (%) Based on Pooled Data for Two Years Summer 2010 And 2011.

The probable mechanism of action may be (I) Protein Synthesis - Microtubule assembly inhibitors that inhibits the assemblification of microtubules, polymerization of tubulin (the major protein content) which is very much essential for formation of cell wall. As a result, arrestation of cell division, formation of polynucleates cells and eventually inhibition of root and plant growth.

(II) Fatty acid (Lipid) Biosynthesis: ACEase (Acetyl Elongase) inhibition (Very long fatty acid chain inhibition). The chemicals inhibit the cell division and elongation in seedling shoots before they emerge above ground and (iii) Un couplers (Membrane Disruption): Inhibition of Oxidative Phosphorylation

Botanicals are having very weak phenolic acids, but these will be recognizably acidic properties particularly in moist soil. A Hydrogen ion can break away from the -OH group and transfer to a base. The position of equilibrium lies well to the left.





Phenolic acids may lose a hydrogen ion because the phenoxide ion (and Hydroxonium ion) formed is stabilized to some extent. The negative charge on the oxygen atom is de-localized around the ring through resonance action. The more stable the ion is, more likely it is to form. One of the lone pairs on the oxygen atom overlaps with the delocalized electrons on the benzene ring. Formation of stable phenoxide ion triggers its acidic nature which attacks the long chain and causes ACEase inhibition [8].

Herbal Medicine

It has been observed that wide scope of preparing the Herbal Medicine from many weeds like *Jatropha multifida* (Dettol Plant), *Hibiscus subdarifa,* (Tak Bhindi), *Pergularia daemia* (Chagalbati), *Croton sparsiflorus* (Bon marich), *Leucas aspera* (Swetdhron), *Cynodon dactylon* (Dub ghash), *Cyperus rotundus* (Muthaghash), *Tridax procumbans* (Mahavringaraj), *Heliotropium indicum* (Hatisur), *Centella asiatica* (Thankuni), *Allium vineale* (Bon onion), *Gynandropsis pentaphylla* (Dantan plant),, *Ocimum*

basilicum (Bon Tulsi), *Biophytum sensitivum* (Life plant), *Cannabis sativum* (Bhang), *Leonurus sibiricus,* (Lal dhron), *Artemisia capillaries* (Rag weed), *Tephrosia purpurea* (Bon neel), *Physalis minima,* (Bon Makao), *Ageratum haustonianum* (Ghandhali) etc.. Some findings are *Heliotropium indicum* (Hatisur) leaf extract is used against Jai Bangla eye disease; *Heliotropium indicum* (Hatisur) juice mixing with C*alotropis gigantea* (Akanda) Juice + *Brassica juncea* (Mustard) oil against Scabies disease; White latex of *Pergularia damea* (Chagalbati) against Sweti disease; *Calotropis* leaf and stem latex use with slightly hot kerosene oil against swallow and pain; *Solanum torvum* (Choto bon begun) fruit against bat disease; *Croton sparsiflorus and Jatropha multifida* against cut and wounds [19].

Beside the above leading uses, *Eichhornia* and *Parthenium* are using as biogas; *Jatropha* in biodiesel, *Eclipta* oil as hair dye, *Cyperus rotundus* nut oil as incense in agarbatti preparation, *Parthenium hysterophorus, Eichhornia crassipes,* and *Leptadenia pyrotechnica* (Khimp plant of family Asclepiadaceae) are widely using for Paper pulp, Table cushion, Basket, Cork etc. *Oryza rufipogon* may be used as breeding purpose with local HYV to produce deep water / Shallow water/ Flash flood stagnant rice varieties [6].

Management through Ecosafe Organic Chemical Herbicides

The invasive weeds along with general weed biodiversity in University campus area, municipal areas, roadsides, government offices like ICAR fodder farm, BSF, NTPC, Airport, Singur operation etc. In West Bengal were managed through various programmes undertaken during last one decade proved satisfactory results by using sole or mixture of Glyphosate 41 SL @ 3.5 $_{kg}$ ha^{-1}, Glyphosate71 SG @ 3 $_{kg}$ ha^{-1}, Paraquat dichloride 24 SL or EC @ 2 $_{kg}$ ha^{-1}, Glyphosate 71 SG + Oxyfluorfen 23.5 EC @ 2 $_{g}$ liter^{-1} water, Glyphosate 71 SG @ 3 $_{kg}$ ha^{-1} + 2,4 D EE @ 500 $_{g}$ ha and Diuron 80WP @ 15 $_{kg}$ ha^{-1} [20, 1]. Repetition of 2-3 sprays annum^{-1} is essential for good control.

On Farm Trials and Awareness Programmes

The on farm trials conducted in the nearby villages of University campus on the agri skill development of *Parthenium* compost preparation, bio herbicide raw extract preparation (Figure 3) and application on transplanted SRI, use of *Cyperus* nut oil in agarbatti preparation etc. Through awareness and demonstration program me. All these programmes proved pleasing results as farmer's acceptance on managing invasive weed plants through utilization or chemical is promising. To create more awareness among the common peoples including the farmers is another alternative for mass eradication of these invasive weeds. In India during the last few years many awareness programmes have been conducted by Ministry of Agriculture, Government of India; Indian Council Of Agricultural Research (ICAR); Directorate Of Weed Science Research (DWSR); Directorate of Agriculture in different States etc. At West Bengal more than 100 such Programmes have been conducting per annum by Bidhan Chandra Krishi Viswavidyalaya (BCKV) during the last five years through Directorate of Extension Education; Krishi Vigyan Kendra and Adhoc projects sponsored by Corporates or ICAR. The Weed Science, Department of Agronomy alone has been conducting around 25 such awareness programmes per annum at various districts of West Bengal since 2006-07 [4,9,19,21] organized by the author. The benefits of these awareness programmes are reported to be satisfactory.

Figure 3: On Farm Management of Invasive Weed through Botanicals and Chemical Herbicides.

Final Consideration

In conclusion Invasion of plants is a natural phenomenon. Survey and Surveillance is essential to find out their spreading. Research is to be done to find out its limitation through possible uses. Awareness is needed to campaign about it's possible management through utilization and lastly all sectors of the society - the scientists and officers of Institutions, Government & NGOs, farmers, students, and even the public should be involved in managing these invasive plants with keeping environment safe. Both Central and State government should make sustainable policies to stop invasion and for managing invasive weeds in consultation with scientists.

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