Advanced Research in Agriculture and Organic Farming

Research Article

Sustainable Options for Managing Invasive Alien weeds, Biodiversity Conservation and Enhancement of Farming Livelihoods

RM. Kathiresan*

Annamalai University, Tamil Nadu, India

The role of changing climate in triggering the invasive behaviour of certain weed species resulting in a shift in the floristic composition of weeds is becoming obvious. Such a scenario warrants the need for multiple options to address a particular weed problem rather than relying upon unified approach. Accordingly, It exploring the feasibility of engaging a systems approach of integrated farming, indigenous knowledge base and weed utility offers good weed solutions that reinforces sustainability. Scientists agreed that the planet's temperature has risen by 0.5°C since 1900 and will continue to increase at a faster rate. Because of change in land use pattern, the terrestrial biosphere of 21st century would probably be further impoverished in species richness. The biosphere will be generally more in weedy [1]. Options for integration in a weed management programme are wide, as several elements such as pattern of cropping, land management practices, agricultural inputs and component enterprises offer ancillary benefits of managing weeds and these could be integrated with weed control options such as mechanical, biological and chemical measures. Swaminathan [2] reported an integrated farming system approach to address not only a reliable way of obtaining fairly high productivity with substantial fertilizer economy, but also a concept of ecological soundness leading to sustainable agriculture.

Altered Rainfall Pattern and Weed Invasivity

Global warming directly reflects on rising sea levels due to melting of ice caps and natural expansion of sea water as it becomes warmer. Consequently, areas adjoining the coast and wetlands could be frequently flooded and the distribution pattern of monsoon rains may alter, through more intense downpours, storms and hurricanes. The meteorological data available at Annamalai University [3], for the tail end of the Cauvery river delta region of Tamil Nadu State, India, shows that the average annual rainfall during the last 20 year has increased by 233 mm compared to the average of the previous 10 year (1588 and 1355 mm, respectively). In contrast, annual evaporation has reduced by 453 mm (2153 and 1700 mm, respectively) (Table 1).

A phytosociological survey of floristic composition of weeds in this region reveals recent invasion of the wetland rice fields by alien invasive weeds *Leptochloa chinensis* and *Marsilea quadrifolia* (Table 2). These two weed species dominated the native weeds such as *Echinochloa* sp. by virtue of their amphibious adaptation to alternating flooded and residual soil moisture conditions prevalent during recent years in this region [4].

Leptochloa chinensis owes its invasive behaviour to a longer life span that extends in to the relay crop of mung bean after transplanted rice. These two crops differ widely in soil conditions that they prefer, with transplanted rice surviving in inundated water, where as mung bean thrives in residual soil moisture below 30%. *Leptochloa chinensis* shows adaptation to both the extremes of climate, within the same generation. *M. quadrifolia* is tolerant to most of the grass killer herbicides used like butachlor. Further, frequent floods favour its perpetuation.

Surveys in the distributary channels of lake Veeranum during 1990 and 2010 (Table 3) indicated that the invasive alien [5] species *E. crassipes* has invaded the watersheds in north Tamil Nadu. This is because the distribution from the lake Veeranum during the period before 1990 was mainly from the river Cauvery, which received water from the adjoining state of Karnataka through Mettur Dam. Accordingly, water was flowing with higher velocity during monsoon periods commencing from June extending upto December. However, after 1990, following a dispute between the two states of Karnataka and Tamilnadu, these channels primarily served the purpose of drainage outlets following flash floods. Such events were frequent during this last 20 year segment. A comparatively lesser quantity of river water received during August and September was also distributed through the channels. The flood waters from inland wetlands have served as infestation sources of invasive species such as *E. crassipes.*

Increasing Temperature Regimes and Invasive Behaviour of Weeds

Introduced from Central America as a drought tolerant species

Table 1: Rainfall and evaporation pattern in the Cauvery river delta region.

Period	Annual rainfall (mm)	Annual evaporation (mm)
1980 – 1990	1355	2153
1990 – 2000	1483	1898
2000 – 2010	1588	1700

***Correspondence to:** RM. Kathiresan, Annamalai University, Tamil Nadu, India, E-mail: rmkathiresan.agron@gmail.com

Received: June 11, 2018; **Accepted:** July 20, 2018; **Published:** July 27, 2018

Table 2: Floristic composition of weeds in rice fields irrigated by channels in Cauvery river delta (Importance value Index %).

Weed species	Channel I		Channel II		Channel III	
	1990	2010	1990	2010	1990	2010
Echinochloa sp.	25.56	7.93	28.48	8.01	27.52	4.02
L eptochloa chinensis	22.74	30.41	24.81	29.85	23.64	32.17
Cyperus rotundus	17.23	12.50	22.28	17.25	17.01	4.80
sphenoclea zeylanica	2.02	6.28	0.68	2.17	1.68	7.24
M. quadrifolia	1.46	39.61	0.63	41.84	0.46	40.32

Table 3: Survey of aquatic weeds in five of the distributary channels of Lake Veeranum in Tamil Nadu (Importance Value Index, %).

Weed species	Channel I		Channel II		Channel III		Channel IV		Channel V	
	1990	2010	1990	2010	1990	2010	1990	2010	1990	2010
Ipomoea reptans	10.3	6.4	21.3	4.8	14.6	3.1	19.6	6.0	27.2	2.9
Typha angustata	1.3	0.2	-	-	2.7	-	7.2	2.0	-	-
Leptochloa chinensis	24.30	-	31.0	4.2	19.8	4.9	12.6	-	7.4	1.7
Eichhornia crassipes	-	39.42	-	46.4	-	42.6	7.8	58.6	-	63.4

Table 4: Temperature regimes and root biomass enlargement in *Prosopis*.

Mean annual temperature (ºC)	Mean annual increase in root biomass (kg)	Mean annual increase in shoot biomass (kg)
28	1.9	42
30	4.4	47
32	6.2	56

suitable for afforestation in arid and semi arid zones of India in 1877, *P. juliflora* has invaded many parts of India. Remote sensing data has predicted expansion of the species in Gujarat at the rate of 25 km^2 per yr. Reports predict that by the year 2020, more than 56% of the area in Banni, with rich bio-diversity and grassland ecosystem, would be under Prosopis. The most potential invasive feature of this species is typical greater assimilate partioning towards root, leading to extraordinary enlargement in the root mass with rich food reserves, aiding rapid and robust regeneration after mechanical lopping or after revival of ecological stress conditions such as drought or inundation. Studies at Annamalai University have shown that root enlargement in Prosopis species is greatly influenced by the temperature regime of the locality. The annual increase in root biomass is greater in areas where the mean annual temperature is higher in comparison to areas of lesser mean annual temperature (Table 4). Greater nutrient use efficiency of these invasive species favours their survival in newly introduced areas [6-9] and this ability also helps in their wide spread.

Increase in shoot biomass due to increasing temperature, though observed, is not as significant as the increase in root biomass. Increase in root biomass largely contributes to the weed's ability to tolerate climatic extremes such as peak summer associated with high temperature and water scarcity and peak monsoon winter with water inundation and flooding. This adaptation favors the weed to predominate over other native flora that is susceptible to any one of the two extremes.

Another similar alien weed of wide occurrence in Asia is *Parthenium hysterophorus*. This weed, originated in Gulf of Mexico and Central South America, has invaded India, Pakistan and Srilanka through cereal and grass seed shipments from USA during 1950s. The weed has been predicted to increase its invasivity due to ecological niches provided by frequent flooding and higher CO_2 resulting from global warming [10]. These weeds are observed to possess periodicity of germination and phenology to evade environmental stress conditions [11]. Prevailing maximum temperatures between 30 and 34ºC linked to available soil moisture status of 40-60% favour germination and flowering, whereas temperatures above 35ºC (coinciding with summer) or excessive soil moisture (coinciding with monsoon winter) above 80% is detrimental. The weed has adapted to complete two generations within one year, programming its phenology between these climatic extremes (Table 5).

Farming Elements Offering Weed Solutions

Fish culture and poultry rearing in rice

Annamalai University has evolved an innovative integrated rice farming system to manage weeds. Through 12 years of rigorous institutional field experimentation with statistically replicated experimental design, the best suited component elements of fish culture and poultry rearing were selected from among rabbit, duck, fish and poultry birds for integration. The optimum mode of integration was also determined, including stocking density of fish fingerlings and poultry birds, size of fish trenches, size of poultry cages and nature and quantity of agro inputs [12].

The herbivorous feeding habits of fish fingerlings contributed to weed suppression while the acidic pH and allelomediatry principles of poultry waste interfered with weed seed germination [13]. These positive contributions from the two component farming elements were responsible for suppression of both the invasive alien species in rice ecosystems in three districts as shown in Table 6. Pest incidence in rice as shown in Table 7, is also reduced due to integration of the fish culture and poultry components, because of the feeding habits of fish that suppresses the egg masses, larvae and alternate weed hosts of pests (Figure 1).

Goat in upland crops

This technology involve rearing goats and using them for manuring as well as plant protection in crops that are grown during the succeeding cropping season. Under existing goat rearing modes, farmers rear goats exclusively on herbs and vegetation available on social and ranching sites. In this intervention farmers are trained to rear the goats allowing them to graze on the weed vegetation (mostly perennial grasses like *Cynodon dactylon* and sedges like *Cyperus rotundus*) that predominate the cropped lands during the off-season. Reduction in weed biomass in the farmer's fields because of grazing by goats in off-season (Figure 2) was higher in Cuddalore and Nagapattinam districts compared to Villupuram. This is attributed to closer grazing of goats for want of excessive or adequate flushes of weed vegetation in the off-season in these two districts compared to Villupuram.

Use of pigs for weed control in rice

Experiments during consecutive rice seasons revealed that the use of pigs for burrowing the puddled field before transplanting of rice was found better than other off-season land management techniques *viz*. summer ploughing and glyphosate spray @ 1.0 kg a.i/ha 45 d before transplanting in reducing nut sedge population (Figure 3). This treatment in combination with incorporation of tamarind husk @ 10 t/ha and hand weeding recorded the highest biomass and weed control indices (Table 8).

Burrowing of puddled field by pigs before transplanting of rice, brought all the underground tubers of *C. rotundus* to the surface, many of which were eaten by the pigs, whilst others were skimmed away before final land preparation and levelling. Thus, the treatment was very effective in depleting the soil reserve of tubers of *C. rotundus* which were chiefly responsible for the perennation of the world's worst weed.

Lotus as rice farming component complimenting rice weed control

Inclusion of Lotus (*Nelumbo nucifera* G.) as a rice farming component in trenches running along one side border of rice fields occupying ten percent of rice area is observed to compliment rice weed control by 36 per cent. The biomass of invasive alien weeds *M.quadrifolia* was reduced by 72 per cent and that of *L.chinensis* by 44 per cent and total weed biomass by 36 per cent, with the inclusion of Lotus (Table 9).

Integrated control of invasive *Eichhornia crassipes*

This strategy for managing the aquatic weed water hyacinth [14] was through the integration of the insect biocontrol agent *N.eichhorniae / bruchii* with the use of dried plant material of the medicinal herb *C. amboinicus*. This herb is allelopathic on water hyacinth through the mechanism of membrane disruption and electrolyte leakage and the dried plant powder easily got absorbed into the weed through the leaf

Table 5: Phyto-eco-sociology of *Parthenium* in Veeranum Ayacut region (Mean of 2000 and 2001).

Mon	*Parthenium* important value (%)	Available soil moisture (%)	Mean monthly maximum temperature (ºC)
January	-	-	28.6
February	76	55	32.0
March	81	42	32.4
April	84	32	34.3
May	11	29	37.5
June	-	25	36.2
July	-	29	36.0
August	-	40	34.6
September	48	42	33.7
October	51	58	31.6
November	32	81	29.8
December	-	86	28.0

Rice + Fish + Poultry Components

Figure 1: Fish Culture and Poultry components.

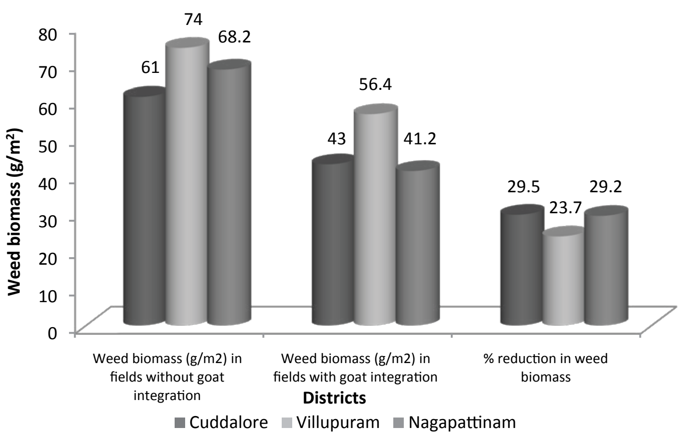

Figure 2: Weed suppression due to goat grazing in upland clusters.

Table 6: Weed suppression due to fish and poultry components in rice.

Location	Weed count/m²				Weed biomass (g/m²)			
Districts	*L. chinensis*		*M. quadrifolia*		*L. chinensis*		*M. quadrifolia*	
	Rice alone	R+F+P	Rice alone	R+F+P	Rice alone	R+F+P	Rice alone	R+F+P
Cuddalore	16	11	38	22	56	38	42	26
Villupuram	9	7	26	19	42	31	46	32
Nagapattinam	21	13	42	27	62	34	32	21

Table 7: Rice + Fish + Poultry and pest incidence in rice.

Districts	Leaf damage in after 40 days (%)		*Nilaparvata lugens* population after 7 days	
	Rice alone	Rice + Fish + Poultry	Rice alone	Rice + Fish + Poultry
Cuddalore	23.0	18.0	11.0	8.0
Villupuram	21.0	17.0	14.0	10.0
Nagapattinam	17.0	14.0	15.0	11.0

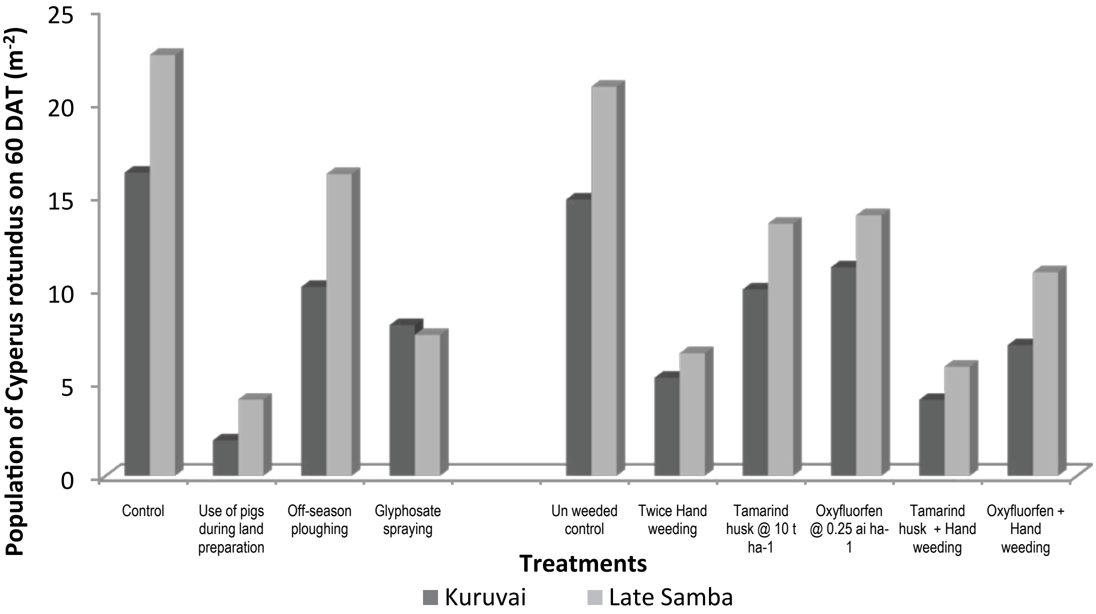

Figure 3: Population of *C. rotundus* on 60 DAT (m^{-2}).

Table 8: Weed biomass (g/m^2) and weed control index (%) as influenced by ploughing and weed management.

	Mean value	
Main treatments	**Kuruvai**	**Late samba**
Control	-	-
Use of pigs during land preparation	62.9 (47.8)	59.9 (51.4)
Off-season ploughing	49.8 (35.0)	51.4 (40.8)
Glyphosate spraying	58.4 (41.2)	55.3 (47.3)
SEd±	1.04	1.09
CD (0.05)	2.08	2.18
Sub-treatments		
Unweeded control	-	-
Twice hand weeding	58.0 (58.1)	56.8 (53.9)
Tamarind husk @ 10 t/ha	52.5 (29.5)	50.3 (36.7)
Oxyfuorfen @ 0.25 kg ai/ha	51.7 (32.3)	49.4 (34.3)
Tamarind husk + hand weeding	59.3 (51.1)	57.3 (56.4)
Oxyfluorfen + hand weeding	55.6 (36.2)	53.5 (42.1)
SEd±	1.12	1.13
CD (0.05)	2.24	2.25

Table 9: Weed Biomass and weed control index in Rice + Lotus System.

Treatments	*M.quadrifolia* (g/m^2)	*L.chinensis* (g/m^2)	Others (g/m^2)	Total (g/m^2)
Rice	142	93	68	303
Rice + Lotus	39.8	52	101	193
Weed Control Index (%)	**71.97**	**44.08**	**-48.52**	**36.30**

scrapping made by the insects [13,15]. Observations made on the weed population at quarterly intervals after implementing this approach in selected water sheds of four districts are furnished in Table 10.

A mode of utility for the aquatic weed *E. crassipes* was shown to be successful with the extraction of nanofibers using three methods; chemical (alkali and peroxide) and mechanical treatments (TEMPO mediate oxidation treatment). The obtained nanofibers from the weeds using the above three treatments was estimated to be about 5-100 nm in diameter and lengths of several um. From the nanofibers transparent thin film, transparent sheet, paper and the transparent biodegradable nanocomposites were also prepared. The biodegradability test conducted following OECD Guidelines for the Testing of Chemicals OECD 30IB clearly indicates that the compound is readily biodegradable (Patent Application No-1877/DEL/2010 filed on 11/08/2010 in Intellectual Property of Rights. New Delhi on TEMPO (2, 2, 6, 6 – Tetramethylpiperidinyl – 1 – oxyl radical) mediated catalytic oxidative synthesis of cellulose nanofibers 5 – 50 nm size from the aquatic weed water hyacinth).

Conclusion

The role of changing climate in triggering the invasive behaviour

Table 10: Weed population of *Eichhornia crassipes.*

Location	Weed population (no./m^2)				
	January 2010	April 2010	July 2010	October 2010	January 2011
Cuddalore	34	4	-	11	20
Villupuram	22	2	4	7	15
Nagapattinam	31	6	-	14	17
Thiruvannamalai	27	9	4	12	14

of certain weed species resulting in a shift in the floristic composition of weeds is becoming obvious. Such a scenario warrants the need for multiple options to address a particular weed problem rather than relying upon unified approach. Accordingly, exploring the feasibility of engaging a systems approach of integrated farming, indigenous knowledge base and weed utility offers good weed solutions that reinforces sustainability.

References

1. Walker B, Steffen W (1997) An overview of the implications of global change for natural and managed terrestrial ecosystems. *Conservation Ecology* 1(2): 2.
2. Swaminathan MS (1987) Inaugural address at the International Symposium of sustainable agriculture. The rate of decomposition of green manure crops in rice farming system. International Rice Research Institute, Los Banos, Philippines.
3. The Hindu. Report from The Director and Meteorologist, Regional Meteorological Centre, Chennai, India. 2005.
4. Yaduraju NT, Kathiresan RM (2003) Invasive weeds in the tropics. In: Proceedings of the 19th Asian – Pacific Weed Science Society Conference, Manila, Philippines.
5. Kathiresan RM (2014) Management of Invasive alien weeds under changing climate. DWR-Souvenir, Celebrating Silver Jubilee (1989-2014). Directorate of Weed Research, Jabalpur, India. 140 p.
6. Bargali SS, Singh RP, Singh SP (1992) Structure and function of an age series of eucalypt plantations in Central Himalaya, II. Nutrient dynamics. Annals of Botany. 69(5): 413-421.
7. Bargali SS, Singh SP (1991) Aspect of productivity and nutrient cycling in an 8-year old Eucalyptus plantation in a moist plain area adjacent to Central Himalaya, India. Canadian Journal of Forest Research 21(9): 1365-1372.
8. Bargali SS, Singh SP (1995) Dry matter dynamics, storage and flux of nutrients in an aged eucalypt plantation in Central Himalaya. Oecologia Montana 4: 9-14.
9. Bargali SS (1995) Efficiency of nutrient utilization in an age series of *Eucalyptus tereticornis* plantations in the tarai belt of Central Himalaya. Journal of Tropical Forest Science 7(3): 383-390.
10. Adkins SW, Navie SC, Dhileepan K (2005) *Parthenium* weed in Australia – Research progress and prospects, pp.11-27. In: *Proceedings of Second International Conference Parthenium Management,* Bangalore, India.
11. Kathiresan RM, Gnanavel I, Anbhazhagan R, Padmapriya SP, Vijayalakshmi NK, et al. (2005) Ecology and control of parthenium invasion in command area. In: Proceedings of second international Conference on Parthenium Management, Bangalore, India.
12. Kathiresan RM (2007a) Linking Environment and weed management through integrated farm management, pp.21-26. In: *Proceedings of the 21st Asian – Pacific Weed Science Society Conference*. Colombo, Sri Lanka.
13. Kathiresan RM (2007b) Integration of elements of farming system for sustainable weed and pest management in the tropics. Crop Protection 26: 424-429.
14. Kathiresan RM (1998) Allelopathic control of water hyacinth. In: Newman, J.R.(Ed.), Annual Report 1997 of Centre for Aquatic Plant Management, UK, p: 54-56.
15. Kathiresan RM (2000) Allelopathy Potential of Native plants against water hyacinth. Crop Protection 19: 705-708.