*Pak. J. Weed Sci. Res., 18: 271-282, Special Issue, October, 2012*

# UTILITY TAG, FARMING ELEMENTS AND ITK FOR SUSTAINABLE MANAGEMENT OF WEEDS IN CHANGING CLIMATE

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## ABSTRACT

*A predominance of small holder farms in Asia offers scope for using component elements in a farming system for sustainable management of weeds that behave invasive in a changing climate. Altered precipitation, evaporation and temperature patterns due to climate change have resulted in weed flora shifts in northern coastal districts of Tamilnadu state, India. In particular, there has been a preponderance of invasive alien species such as Leptochloa chinensis (L.) and Marsilea quadrifolia L. in wetlands, Trianthema portulacastrum L. in uplands and Eichhornia crassipes Mart. Solms in aquatic systems. Research undertaken at Annamalai University in India is providing some alternative solutions to manage these problematic weeds. Innovative use of fish culture and poultry rearing in rice fields was shown to compliment weed control through 400 on-farm experiments, with biomass reductions of invasive alien species ranging from 31 to 38 per cent, in these districts. Similarly, using goats for off-season grazing reduced the biomass of weeds in upland crops. For example, biomass of the dominant T. portulacastrum declined by 23 to 29 per cent in 500 on-farm participatory experiments. Involving pigs for burrowing the puddled fields and addition of Tamarind husk complimented control of rice weeds especially nut sedge, which was reduced by 61 per cent. The invasive weed E. crassipes in aquatic systems was controlled in seasonal waterbodies within a season, by innovative and integrated use of insect agent (Neochetina eichhorniae) and plant product of Coleus amboinicus L. Utility modes for consuming the extensive biomass of E. crassipes have also been compared (viz., manure, cattle feed and nanofiber extraction). Results indicate that manurial use and tempo mediated extraction of nanofibers offers an innovative tag of utility for management of this weed*

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**Keywords:** Climate change, Invasive alien weeds, Weed utility, Farming elements, Sustainable management.

## INTRODUCTION

The 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 well be

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integrated with the weed control options such as mechanical, biological and chemical measures. Swaminathan (1987) 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. A judicious combination of any one or more of the enterprises with a cropping component was observed to result in better utilization of available resources through effective recycling of residues or wastes. It also offered employment for family labour during the off-season, making the farm a viable unit (Behera and Mehapatra, 1998). Sustainability in managing weeds under varied farming conditions such as wetland rice farming and rainfed or irrigated upland farming with these integrations and the consequences of such integration on crop pest complexes are discussed in this paper. Aquatic systems are more delicate considering the weed management options as their impact is reflected on multiple resources like water, soil, crops and associated flora and fauna. Further, the invasive spread of the weeds in the system is much faster. However, the absence of soil interface, unlike in terrestrial systems could either hasten or impede the efficacy of management strategies depending upon the nature of such options. The absence of soil interface in the aquatic system that largely contributes to rapid degradation of allelochemicals, triggers the scope for integrating allelopathic interference as one of the tools in managing weeds. Though allelopathic suppression of weeds could not be construed as an alternate to replace synthetic herbicides, the same can fit in an integrated weed management programme very well as a prime component. Research undertaken in these areas of alternative solutions or weed problems at Annamalai University, India are reviewed.

**Weeds and Changing Climate**

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 the Annamalai University, for the tail end of the Cauveri river delta region of Tamil Nadu State, India, shows that the average annual rainfall during the last 20 years has increased by 233 mm compared to the average of the previous 10 years (1588 and 1355, respectively). In contrast, annual evaporation has reduced by 453 mm (2153 and 1700, respectively) (Table-1).

A phytosociological survey of floristic composition of weeds in this region reveals the recent invasion of the wetland rice fields by the alien invasive weeds *L. chinensis* and *M. quadrifolia* (Table-2). These two weed species dominated over 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 (Yaduraju and Kathiresan, 2003; Kathiresan, 2005).

**Table-1. Rainfall and evaporation pattern in the Cauvery river delta region of India.**

| Period | Annual Rainfall (mm) | Annual Evaporation (mm) |
|---|---|---|
| 1980-1990 | 1355 | 2153 |
| 1990-2000 | 1483 | 1898 |
| 2000-2010 | 1588 | 1700 |

*L. chinensis* owes it's 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 the soil conditions that they prefer, with transplanted rice surviving in inundated water, where as mung bean thrives in residual soil moisture below 30 per cent. *L. chinensis* shows adaptation to both the extremes of climate, with in the same generation. *M. quadrifolia* is tolerant to most of the grass killer herbicides used like butachlor (Machete). Further, frequent floods do favour it's perpetuation.

**Table-2. Floristic composition of weeds in rice fields irrigated by channels in Cauvery river delta (Importance Value Index %), India.**

| 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. chinensis* | 22.74 | 30.41 | 24.81 | 29.85 | 23.64 | 32.17 |
| *Cyperus rotundus* L. | 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 |

A major weed that has been invading irrigated upland agroecosystems in several tropical Asian countries is *T. portulacastrum.* This weed is reported to have originated from tropical Africa and has invaded several continents *viz*., Australia, Africa and Asia (Rawson and Bath, 1984). A survey conducted in different irrigated upland crops of Veeranum Ayacut in Tamilnadu, India indicated that *T. portulacastrum* predominates as the dominant species in three crops *viz*., sugarcane, sunflower and gingelly with important value index percentages of 28.73, 26.83 and 25.99 respectively. This weed tops the list of 15 weed species recorded in all these crops in different locations (Kathiresan, 2004). One of the most important characteristics responsible for it's invasiveness is thermal induction of seed germination once soil temperature reach around 35º C. This results in synchronized and mass germination of seeds, producing a green carpet of seedlings. In a field study conducted at Annamalai University, it was observed that, increasing soil temperature with the summer months of June and July triggered the mass germination of seed of this weed, which led to suppression of the native species. The seeds of this weed undergo dormancy during winter and thermo-induction to break the dormancy requires soil temperatures above 35º C which normally coincides with the June, July months (Sundari and Kathiresan, 2001).

Surveys in the distributary channels of lake Veeranum during 1990 and 2010 (Table-3.) indicate that the invasive alien species *E. crassipes* has invaded the watersheds in north Tamilnadu. This is because, the distribution from 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, the water was flowing with higher velocity during the 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*.

**Table-3. Survey of Aquatic weeds in five of the distributary channels of Lake Veeranum in Tamilnadu (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 |
| *Ipomea reptans* Per. | 10.3 | 6.4 | 21.3 | 4.8 | 14.6 | 3.1 | 19.6 | 6.0 | 27.2 | 2.9 |
| *Typha angustata* L. | 1.3 | 3.2 | - | - | 2.7 | - | 7.2 | 2.0 | - | - |
| *L. chinensis* | 24.30 | - | 31.0 | 4.2 | 19.8 | 4.9 | 12.6 | - | 7.4 | 1.7 |
| *E. crassipes* | - | 39.42 | - | 46.4 | - | 42.6 | 7.8 | 58.6 | - | 63.4 |

**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 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 (Kathiresan, 2007a). In the NAIP – Comp III – SRLS 36 project, the system that has been optimized and perfected is being disseminated for adoption over 430 farmers holdings (Fig. 1.). In each of the 430 development partners' rice fields, inputs including poultry cages, concrete posts, birds, feed and fish fingerlings were given free of cost for practicing integrated rice + fish + poultry farming in $200m^2$ of rice area. Unlike other rice farming systems demonstrated elsewhere, wherein the component enterprises would remain as separate entities, in this IFS approach, fish poly culture with Catla, Roghu, Mrigal, common carp and grass carp in equal proportions of a stocking density of 2000 fingerlings / ha is taken up in trenches running along the border of one side of rice fields (20 x 10 m). The trenches are one metre deep and with a top width of 0.75 m and bottom width of 0.5 m so that the total dimension is 20 m x 0.75 / 0.5 m, occupying 15 m that contributes for 7.5 per cent of rice area. Broiler birds @ 1 bird / 10 $m^2$ of rice area, are housed in cages (6 x 4' of floor space and a height of 3' so as to accommodate a maximum of 20 birds) that are installed any where in the field using four concrete posts of height 8', 4' buried inside the field and 4' protruding above lifting the cages above crop canopy. The bottom of the cages are made of wire mesh (0.5 sq. inch) so that the broiler waste falls straight into the 10 cm deep water of the rice field. The poultry waste then dissolves and is able to serve both as rice manure and fish feed. This excludes the need for collecting the poultry waste and applying it to the rice field, the task of which is laborious and sometimes wasteful.

The herbivorus feeding habits of fish fingerlings contributes to weed suppression while the acidic pH and allelomediatry principles of poultry waste interferes with weed seed germination (Kathiresan, 2007b). These positive contributions from these two component farming elements are responsible for the suppression of both the invasive alien species in the rice ecosystems in three districts shown in Table 4. Each of these three districts consisted of three villages where 100 farmers with their small or marginal holdings participated in the research as a development partner. Pest incidence in rice as shown in Table 5, is also reduced due to integration of the fish culture and poultry components, because of the feeding habits of fishes that suppresses the egg masses, larvae and alternate weed hosts of pests.

**Figure 1. Integrated rice + fish + poultry farming system.**

**Table-4. Weed Suppression due to Fish & Poultry Components in Rice.**

| Location | Weed count / $m^2$ | | | | Weed biomass g / $m^2$ | | | |
|---|---|---|---|---|---|---|---|---|
| | *L. chinensis* | | *M. quadrifolia* | | *L. chinensis* | | *M. quadrifolia* | |
| Districts | 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-5. 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 |

## Goats in Upland Crops

This technology involves 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* (L.) and sedges like *C. rotundus*) that predominate the cropped lands during the off-season. Simultaneously, collecting the goat manure during the off-season and incorporating them for the crops (millet / vegetable / flower crop) during the rainfed seasons greatly compliments the crop by virtue of improved organic matter, soil nutritional status, pest, disease and weed control (through depletion of soil weed seed bank and suppression of alternate weed hosts for the pest and diseases). This greatly helps control of perennial weeds. However, these goats (reared @ 4/acre or 10/ha) need to be fed with tree loppings and other freely and easily available forages during the cropping season. The development partners of five clusters, each of three villages, were given two goats each (1000 goats in total) free of cost. In return they were asked to integrate them into half an acre of their holding.

The reduction in weed biomass in the farmers fields because of grazing by goats in the 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.

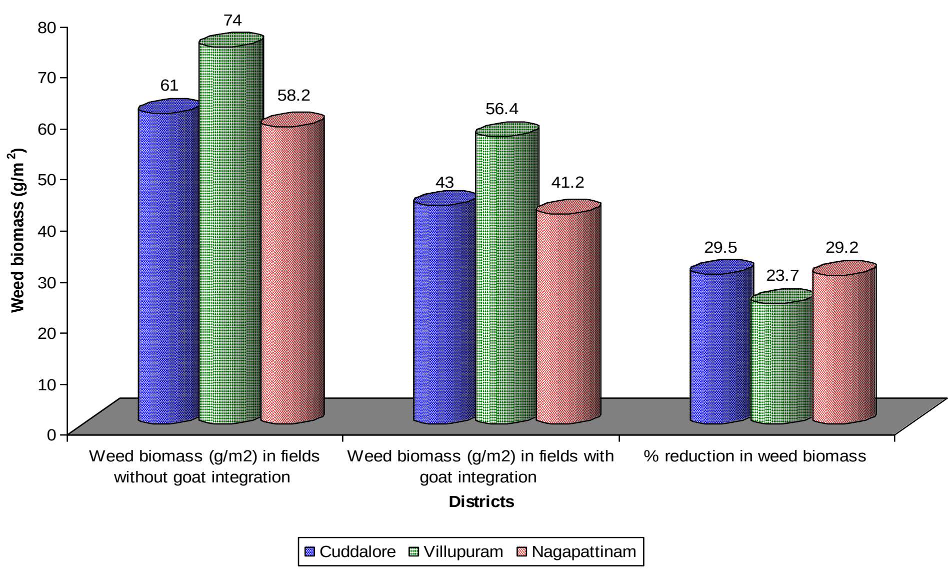


**Figure 2. Weed suppression due to goat grazing in upland clusters.**

**Use of Pigs for Weed Control in Rice**

Experiments during consecutive rice seasons at Annamalai University revealed that the use of pigs for burrowing the puddle fields before transplanting of rice compared better to other off-season land management techniques *viz*. summer ploughing and glyphosate (Roundup) spray @ 1.0 kg a.i $ha^{-1}$ 45 days before transplanting, in reducing nut sedge population (Figure 3). This treatment in combination with incorporation of tamarind husk @ 10 t $ha^{-1}$ and hand weeding recorded the highest bio-mass weed control indices (Table-6).

**Table-6. Weed Control Index (%).**

| Main treatments | Mean Value | |
|---|---|---|
| | Kuruvai | Late Samba |
| Control | - | - |
| Use of pigs during land preparation | 62.93 (47.86) | 59.91 (51.42) |
| Off-season ploughing | 49.85 (35.05) | 51.47 (40.84) |
| Glyphosate spraying | 58.46 (41.22) | 55.30 (47.37) |
| SEd | 1.04 | 1.09 |
| CD | 2.08 | 2.18 |
| Sub Treatments | | |
| Un weeded control | - | - |
| Twice Hand weeding | 58.03 (58.14) | 56.82 (53.93) |
| Tamarind husk @ 10 t $ha^{-1}$ | 52.53 (29.57) | 50.34 (36.76) |
| Oxyfluorfen (Goal) @ 0.25 ai $ha^{-1}$ | 51.72 (32.30) | 49.41 (34.35) |
| Tamarind husk + Hand weeding | 59.39 (51.19) | 57.34 (56.49) |
| Oxyfluorfen + Hand weeding | 55.64 (36.28) | 53.51 (42.19) |
| SEd | 1.12 | 1.13 |
| CD | 2.24 | 2.25 |

This is because, the burrowing of the 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.

**Integrated control of invasive *E. crassipes***

Training in integrated management for the floating aquatic weed water hyacinth in water bodies such as farm or village ponds, irrigation channels and aquaculture habitats, is being given to farmers in several districts. It includes the use of insects, allelopathic plant products, fishes and weed utility. However, the prime strategy for managing the aquatic weed water hyacinth is through the integration of the insect bio-control 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 gets absorbed into the weed through the leaf scrapings made by the insects (Kathiresan, 2000; Kathiresan, 2007b). Farmers are encouraged to cultivate *C. amboinicus* in small areas of their fields and the harvested leaves are made in to dry powder. The insects are being reared in the lead centre. Subsequently, they were released in 24 watersheds spread throughout the district @ 1000 per water shed at the first instance in October 2009. The aqueous extract of dry leaf powder of *C. amboinicus* was sprayed in January 2010. Observations made on the weed population at quarterly intervals are furnished in Table 7.

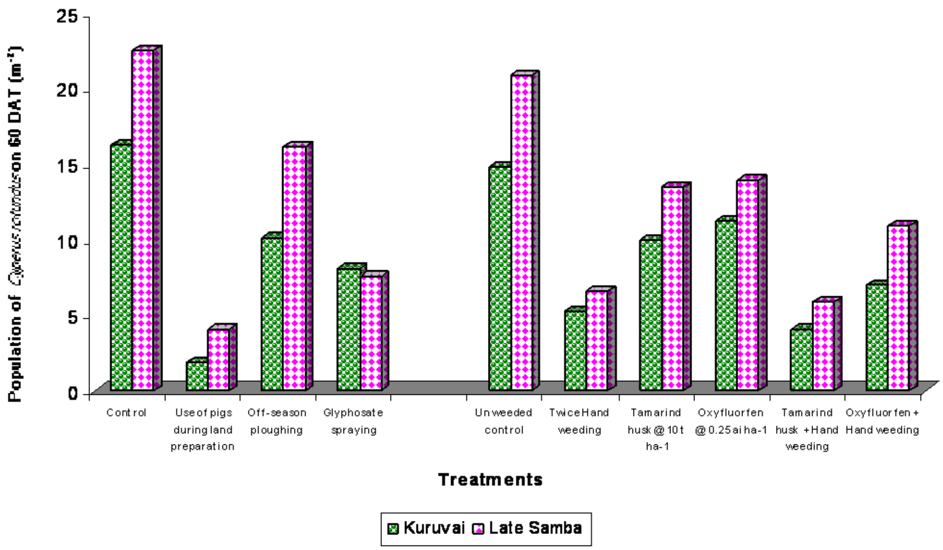


**Figure 3. Population of *C. rotundus* on 60 DAT ($m^{-2}$).**

**Table-7. Weed population of *E. crassipes*.**

| Location | Weed population / $m^2$ | | | | |
|---|---|---|---|---|---|
| | **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 |

Among various modes tried for using this weed in order to affix the tag of utility for speeding up public participation in controlling this weed, mixing dried and powdered water hyacinth upto 15 per cent in the daily ration for cattle, continuously for 15 days, did not cause any adverse change in the health of animals (Table 8.). However, fresh weed vegetation was rejected by the cattle. For utilizing water hyacinth as a manure, various treatments *viz*., water hyacinth compost @ 6.25 t ha$^{-1}$, dried water hyacinth @ 6.25 t ha$^{-1}$, fresh water hyacinth @ 6.25 t ha$^{-1}$ were compared with other organic manures like green leaf manure @ 6.25 t ha$^{-1}$ and Farm Yard Manure 12.5 t ha$^{-1}$ in transplanted rice. Using water hyacinth as compost @ 6.25 t ha$^{-1}$ recorded the highest growth and yield attributes resulting in the highest grain yield of 3850 kg ha$^{-1}$ (Table-9.).

**Table-8. Clinical parameters in calves after 180 days of feeding water hyacinth powder mixed feed.**

| Treatments | Mean | | | | |
|---|---|---|---|---|---|
| | **Body weight (kg)** | **RBC ($x10^6/\mu l$)** | **RBC ($x10^3/\mu l$)** | **Hb (g/dl)** | **PCV (g/dl)** |
| Water hyacinth fed animals | 56 | 6.93 | 9.5 | 11.2 | 31.4 |
| Control group | 58 | 7.01 | 9.17 | 11.4 | 31.6 |
| SEd | NS | NS | NS | NS | NS |
| CD(p=0.05) | NS | NS | NS | NS | NS |

NS - Non-significant; RBC – Red Blood Corpuscles; Hb – Haemoglobin; Packed Cell Volume

**Table-9. Rice grain yield (Kg ha$^{-1}$).**

| Treatments | Mean |
|---|---|
| Water hyacinth compost @ 6.25 t ha$^{-1}$ | 3850 |
| Water hyacinth fresh @ 6.25 t ha$^{-1}$ | 3330 |
| Water hyacinth dried @ 6.25 t ha$^{-1}$ | 3625 |
| Green leaf manure @ 6.25 t ha$^{-1}$ | 3215 |
| FYM @ 12.5 t ha$^{-1}$ | 2898 |
| Control | 2670 |
| Sed | 96.96 |
| CD (p=0.05) | 194.88 |

Another mode of utility for the aquatic weed *E. crassipes viz*. has been the successful extraction of nanofibers using three methods; chemical (alkali and peroxide) and mechanical treatments (TEMPO mediated oxidation treatment). The obtained nanofibers from the weeds (Figure 4.) using the above three treatments was estimated to be about 5 - 100 nm in diameter of the fibers and lengths in several micron meters. From the nanofibers, the transparent thin film, transparent sheet, paper and then the transparent biodegradable nanocomposites were 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").

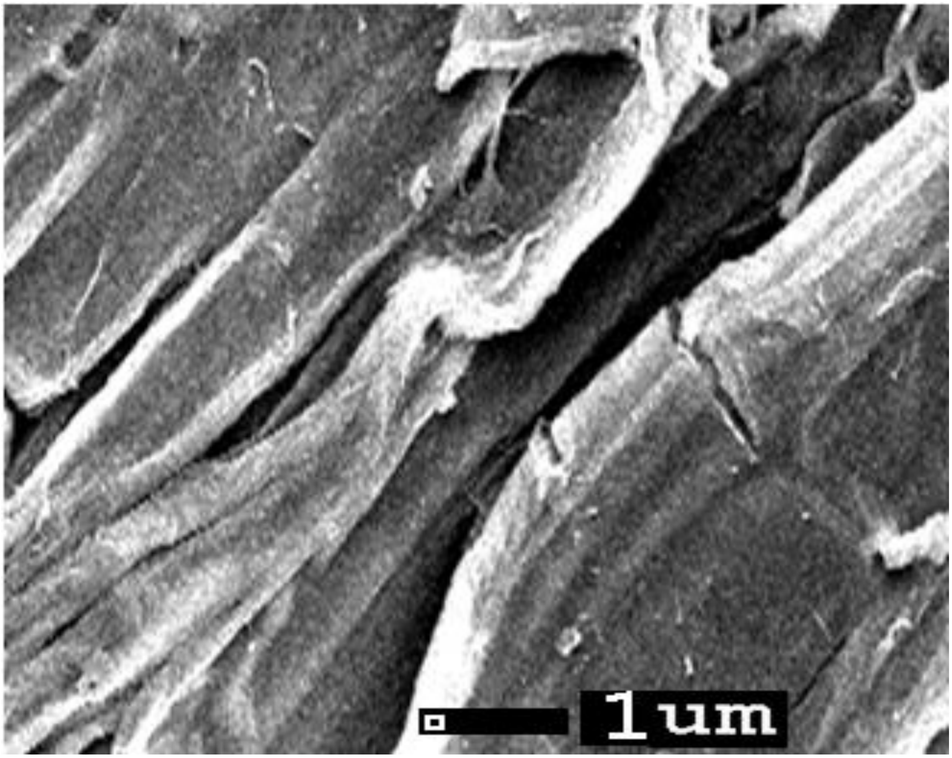


**Figure 4. Sem picture for cellulose nanofibers from waterhyacinth.**

## CONCLUSION

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, exploring the feasibility of engaging a systems approach of integrated farming, indigenous knowledge base and weed utility offers good weed solutions that reinforces sustainability.

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